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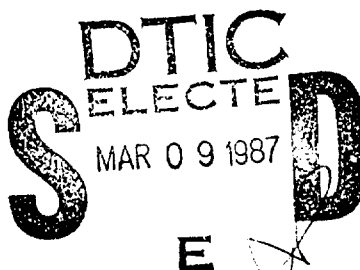
PERSONAL COMPUTER PROGRAM
FOR CHEMICAL HAZARD PREDICTION
(D2PC)

by   C. Glenvil Whitacre
Joseph H. Griner, III
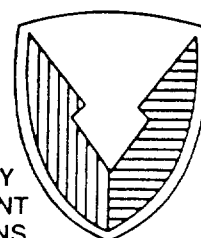Michael M. Myirski
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STUDIES AND ANALYSIS OFFICE

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Aberdeen Proving Ground, Maryland   21010-5423

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PREFACE

The work described in this report was authorized under Project No. 1L162706A553, CB Defense and General Investigations, Technical Area 3-B, Analysis and Integration of Chemical Defense Systems. This work was started in February 1985 and completed in October 1985.

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CONTENTS

1.   SCOPE

1.1   Objective.

It is the object of this report to document a personal computer program that will provide computational assistance in estimating chemical downwind hazard in terms of peak vapor concentration or accumulated dosage.

1.2   Background.

This program is a revision of program D2, which was documented earlier.[1] The methodology is based on DODESB Technical Paper No. 10, Change 3, Methodology for Chemical Hazard Prediction, June 1980.[2]

1.3   Approach.

The program is written in FORTRAN 77 for an IBM compatible personal computer. It is conversational, employing a modified form of menu input with a data base provided for standard chemical agents and munitions. Estimates of hazard distance are made for either the expected peak concentration of vapor, the dosage, or the accumulated dose that an individual might receive at that distance.

2.   DESCRIPTION OF THE PROGRAM

2.1   Organization.

The program is made up of a MASTER and 12 subroutines. It is the function of the MASTER to obtain the required information from the user by selecting the questions to be asked for a given problem. The data that is input and retrieved from the tables is then organized for use by one of the downwind distance calculators (DDS or CDS), which makes the estimate of distance and returns it to the operator. The exchange of information between subroutines is diagrammed in Figure 1.
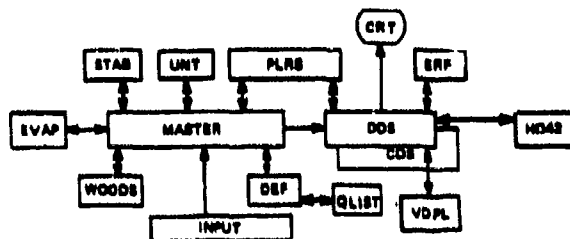

Figure 1.   Information Exchange Between Subroutines

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[1]Whitacre, C.G., and Myirski, M.M. ARCSL-TR-82014. Computer Program for Chemical Hazard Prediction (D2). September 1982. UNCLASSIFIED Report.

[2]Technical Paper No. 10. Methodology for Chemical Hazard Predictions. Department of Defense Explosives Safety Board. March 1975. UNCLASSIFIED Report.

Selection of subroutine DDS or CDS is determined by the choice of dosage or concentration as the exposure index for downwind distance. Subroutine DDS is supported by the error function, ERF, and by subroutine HD42, which is called when an explosive release of HD is requested. Also the plume rise subroutine, PLRS, may be called by DDS or CDS if a rising cloud is to be traced with distance.

The other subroutines support the MASTER. Subroutine EVAP is called to determine the airborne source when the release is by evaporation. STAB is called to select the Pasquill stability category if the meteorological observations are input. When release is in a wooded area, subroutine WOODS is called to select the special diffusion parameters for the particular type of woods. Subroutine PLRS may be called by MASTER to compute the rise of a heated cloud or to initialize for the call from DDS or CDS as explained above.

Subroutines DEF and QLIST work with MASTER to provide variable definitions to the user when needed. DEF also blocks the repetition of request for the same information on successive runs.

2.2   Operation.

The modified menu form of input was developed for this program to accommodate a wide range of user applications and a wide range of experience in the user. A data base is provided for defined storage sites, standard munitions, and agents. The appropriate data for these systems is recovered by selecting the site and system from menus. The menus also include a nonstandard or nondefined option and, when these are used, the needed data is then requested. This approach permits the full power of the models to be drawn out.

The format of the questions is selected by the operator to match his experience level. Four levels are provided. In the most lengthy form, all options are listed and defined with each question. In the shortest form, each question is one line, and the operator is expected to remember the options. However, at any point, the listing for that question may be recalled by answering with question marks. The question is then repeated.

For all numeric inputs, the units are specified in the question; these are generally metric. Other units may be used as long as the strange units are identified by the proper code. Again, question marks (or an error) will cause these codes to be displayed and the question repeated.

When all of the essential questions have been asked for a given run (execution of the downwind hazard estimator), the questions will terminate with the request "ALL OTHER INPUT." At this point, output and control options may be entered. The options may be displayed as tables by typing TAB and the number of the table. The tables are defined as follows:

1. Control options
2. Assessment options
3. Output options
4. Alphabetic listing of parameter codes

This list may be displayed by entering three question marks (???). From the control options, you will see that the code ALL will cause the program to continue

and execute. When execution has terminated, the program will return to the ALL question (ALL OTHER INPUT). Here you may change options and reexecute, restart, or stop. The control options are listed in Tables 1, 2, and 3. These tables may be displayed with TAB 1, TAB 2, or TAB 3 commands as described above.

Table 1. Control Options Run Control

RST	Restart at question 1, clear input blocks
RSN	Rescan from question 2
ALL	Execute downwind calculation
STP	Stop
GTO	Go to entry point specified (question number)
IRT	Return to specified question
INP	Clear input block for specified question
HLD	Hold variable at present value
RLS	Release hold of variable
TAB	Display table
DSP	Question definition
???	List of table codes

Table 2. Assessment Control

IMA	= 0	Dosage (default)
	= 1	Concentration (mg/m^3)
	= 2	Concentration (ppm)
	= 3	Fumigation concentration
2MC	= 1	Do not use 2-minute correction with GB and VX vapor
	= 2	Use 2-minute correction with GB and VX vapor (default value)
MNR	= 0	No effects, no deaths, 1 percent lethality (default)
	= 1	No deaths, 1 percent lethality
	= 2	1 percent lethality
VDP	= 0	Without vapor depletion (default)
	= 1	With vapor depletion

Table 3. Output Control

NOV	= 0	List only input variable
	= 1	List variable and options
	= 2	List variable and options with definitions
OPO	= 0	Output short heading and interpolated distance only (default)
	= 1	Include diffusion parameters and D versus X
	= 2	Above plus components of D
	3	Crosswind width of cloud with distance
OPC	= 0	Use HT max from PLRS
	= 1	List $f(x)$; use HT max
	= 2	Use HT = $f(x)$
	= 3	List $f(x)$; use HT = $f(x)$

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The ALL question may also be used to input new parameter values directly. For example, if you had made an estimate of the hazard distance for a wind speed of 1 m/sec, you could obtain an estimate for 5 m/sec by typing the following:

WND 5.
ALL

The program will rescan the question list, display the current value of each parameter, and stop again at the ALL question for further instruction. The code ALL will then cause it to execute for 5 m/sec and display the new estimate. If multiple parameter changes are required, these are made as separate entries (giving the code and the value for each) before the first ALL response. The stop for the second ALL permits the user to review the parameter values before the next execution. Of course, more changes can be made then, but the program may rescan again and stop again.

The program's decision to rescan after entries in the ALL question is based on the changes that the new parameter value might make in the input questions and the data retrieval from the data base. It is important to realize that this retrieval is repeated with each rescan. Thus, a parameter value that may have been entered as different from the data base would normally be changed back to the data base value on rescan. This change can be avoided if a hold is placed on the specific parameter. This is done by the command code HLD and the parameter code. As an example,

HLD HML

will prevent the height of the mixing layer, HML, from being changed by rescan. Of course, this is not needed unless a nonstandard value has been entered. The hold is released with the command RLS and the parameter code. The HLD command may be stated for any parameter, but it is only useful for those variables that may be changed by rescan. The following is the list of variables with which HLD is effective.

VARIABLES USED WITH HLD

Code	Variable
FMW	Molecular weight
HML	Height of the mixing layer
MNR	Minimum response level
NCI	Concentrations of interest (see Section 4.4)
NDI	Dosages of interest
PMM	Atmospheric pressure
QQQ	Source strength
SXS SYS SZS	Source sigmas
2MC	Two-minute correction control

The control and parameter codes that can be entered through the ALL questions are given in Table 4. These may be displayed by the program with TAB 4. Here the display is in four pages and progresses to the next page each time the return key is pressed.

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Table 4. Options For the ALL Question

Code	Input Variable	
AGN	Agent, see Section 3.6 or DSP 6	
ALL	Control word, execute program	
ALF	Slope of the sigma-y versus x curve	
ARE	Area of puddle	(m^2)
BPT	Boiling point	$(°K)$
BRT	Breathing rate	$(1/min)$
BTA	Slope of the sigma-z versus x curve	
CCT	Cloud cover	$(1/10)$
CHT	Cloud height	(ft)
CRD	Cloud radius	(m)
DLX	Change in x (first cycle)	(m)
DSP	Display question definition	
DST	Diameter of stack	(m)
FMV	Molecular volume	$(cm^3/gm\ mole)$
FMW	Molecular weight	$(gm/mole)$
FRO	Slope of the frost wind profile	
GTO	Control. Go to specified question	
HML	Height of the mixing layer	(m)
HLD	Hold value of symbol	
HRL	Heat released	(cal)
HRS	Local standard military time	(hr)
HST	Height of stack	(m)
HTS	Height of source	(m)
IDD	Number of the day	
IMA	Method of assessment control, see TAB 2	
IMM	Number of the month	
INP	Control. Clear input block for question	
IRT	Control. Return to specified question	
LEN	Length of puddle, downwind	(m)
LOC	Location, see Section 3.2 or DSP 2	
MNR	Minimum response level, see TAB 2	
MUN	Munition, see Section 3.5 or DSP 5	
NCI	Number of concentrations of interest	
NDI	Number of dosages of interest	
NMU	Number of munitions	
NOV	Novice level	
NQI	Number of source intervals	
OPC	Output for stack, see TAB 3	
OPO	Output control, see TAB 3	
PMM	Atmospheric pressure	$(mm\ hg)$
QQQ	Airborne source	(mg)
RDE	Relative density of effluent	
REF	Reflection coefficient (default = 1)	
REL	Method of release, see Section 3.8 or DSP 8	
RLS	Release hold of symbol value	
RSN	Rescan from question 2	
RST	Control. Restart	
SEA	Season, see Section 3.3 or DSP 3	
SKF	Skin factor for subject clothing	

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Table 4. (cont'd)

Code	Input Variable	
SLA	Latitude	(°)
SLO	Longitude	(°)
SMH	Sampling height	(m)
STR	Stability, see Section 3.9 or DSP 9	
SUN	Sun elevation angle	(°)
SUR	Surface type, see Section 3.17 or DSP 17	
SEV	Settling velocity of cloud centroid (default=0)	(m/sec)
SXS	Source sigma x	(m)
SYR	Reference sigma y at 100 m	(m)
SYS	Source sigma y	(m)
SZR	Reference sigma z at 100 m	(m)
SZS	Source sigma z	(m)
TAB	Table display	
TEV	Time of evaporation	(min)
TIM	Time after functioning (INS, HD)	(min)
TMC	Time to met change	(min)
TMP	Temperature	(°C)
TST	Temperature of stack	(°C)
VAP	Vapor pressure	(mm Hg)
VST	Velocity of effluent from stack	(m/sec)
WND	Transport wind speed	(m/sec)
WOO	Woods type, see Section 3.36 or DSP 36	
ZZO	Roughness length	(m)
2MC	Two-minute corrections control, see TAB 2	
???	Display list of tables	

When the program rescans, it repeats the same logic string that was followed in selecting the initial questions. The original questions are relisted along with the current value of the parameter, but the program does not stop for input unless a new question is needed. It will then type the word "INPUT" and stop. All calculations done to establish initial data, such as the selection of the stability class or the amount evaporating from a puddle, will also be recomputed and relisted. The format of this listing will be discussed in Section 4.8.

3.   INPUT

3.1   Question 1, INPUT; NOVICE LEVEL 3, 2, 1, or 0   NOV.

This question is answered by a single digit. Digit 2 will cause the program to list the possible options and a one-line definition for each input variable. Digit 1 will supply a one-line list of options for the multiple choice questions, and digit 0 lists only the questions. The digit 3 will list the options and definitions as described for 2, but will begin by displaying two pages of general information about the operation of the program. The novice level may be changed by a return to question 1 (RST) or by assigning a new value to NOV in the ALL statement.

3.2   Question 2, LOCATION   LOC.

This question is answered by a three-character code that identifies one of the U.S. chemical storage sites or by "NDF" if some other location is being considered. If a listed site is specified, the location, average pressure, and height of mixing layer are recovered from the data base. When the location is not defined by this list, these parameters are requested as required. The following is a list of the option codes.

LOC Code	Location
AAD	Anniston Army Depot
DPG	Dugway Proving Ground and Tooele Army Depot
EWA	Edgewood Area, Aberdeen Proving Ground
JHI	Johnston Island
LBG	Lexington-Blue Grass Army Depot
NAP	Newport Ammunition Plant
PBA	Pine Bluff Arsenal
PAD	Pueblo Army Depot
RMA	Rocky Mountain Arsenal
UAD	Umatilla Army Depot
EUR	USAEUR
NDF	Not defined

3.3   Question 3, SEASON   SEA.

When this question is asked, a three-letter code must be specified to select one of the four seasons. The season is used to select the height of the mixing layer for the listed storage sites. (This question is not asked when the location is listed as NDF.) The following is the list of season codes.

SEA Code	Season
WIN	Winter
SPR	Spring
SUM	Summer
FAL	Fall

3.4   Question 4, HEIGHT OF THE MIXING LAYER   HML.

This question is asked to obtain the height of the mixing layer when it is not defined by the location and season. If a different height is to be specified for a standard location, this is done by declaring the new value in the ALL question (Section 3.15).

3.5   Question 5, MUNITION TYPE   MUN.

Selection from 10 standard chemical rounds may be made or "NON" may be specified for other items. For the standard item, fill weight, agent type, and source dimensions are recovered. For this entry, any three characters may be entered and will be carried through to output. Data is available only on the following items:

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MUN Code	MUN
105	105-mm Cartridge, M60, M360
155	155-mm Projectile, M110, M121A1
8IN	8-inch Projectile, M426
500	500-lb Bomb, MK94
750	750-lb Bomb, MC-1
M55	115-mm Rocket, M55
525	525-lb Bomb, MK116
139	Bomblet, M139
M23	Land Mine, M23
4.2	4.2 Inch Cartridge, M2A1
NON	Nonmunition

3.6 Question 6, AGENT TYPE   AGN.

The agent type requires a two-character code and again will pass any two characters through to output. The physical constants are stored for the substances listed below. Dosage values estimating 1 percent lethality, no deaths, and no effects are retrieved for all of these substances except UDMH. The values for 1 percent lethality were taken from DODESB TP No. 10.[2] The no deaths and no effects are best current estimates based primarily on ORG 40.[3] The following is a list of the agent codes:

AGN Code	Agent	AGN Code	Agent
GA	Tabun	H1	HN-1, Nitrogen mustard
GB	Sarin	H3	HN-3, Nitrogen mustard
GD	Soman	HT	60% HD and 40% T
GF	EA 1212	LL	Lewisite
VX	EA 1701	AC	Hydrogen cyanide
BZ	Incap agent	CG	Phosgene
HY	Hydrazine	CK	Cyanogen chloride
UD	UDMH	DM	Adamsite
HD	Distilled mustard	NA	Nonagent

3.7 Question 7, SPILL OR AIRBORNE SOURCE   QQQ.

For evaporative release, this is the amount that is initially spilled. The EVAP program takes this as Q and then computes Q', which is the amount that becomes airborne. For other forms of release, this is the total amount that is airborne over the release period. The exception is continuous release, which is explained in the next section (3.8).

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[3]Solomon, Irving et al. ORG Report 40. Methods of Estimating Hazard Distances from Accidents Involving Chemical Agent. Operations Researh Group, Edgewood Arsenal, Maryland. February 1970. CONFIDENTIAL Report.

3.8   Question 8, RELEASE TYPE   REL.

The code for release type must be selected from the list given below.

REL Code	Type of Release (REL)
INS	Instantaneous (explosion)
EVP	Evaporation from a puddle formed by a spill
SEM	Semicontinuous. Constant for a finite time.
VAR	Variable. The source is defined as a number of release intervals, each constant for a finite time (maximum of 6).
STK	Release of heated effluent from a stack
STJ	Release from a stack when inertial or jet effect dominates
FLS	Flash fire from ground level
FIR	Fire burning for finite time
IGL	IGL fire for M55 with GB or VX
EVS	Still air evaporation (see Section 4.10)

When the distance is to be based on peak concentration, a time of infinity (1.E36) may be specified for the semicontinuous release, which converts this into a continuous release. In this event the input, Q, is now the rate of release in mg/min.

3.9   Question 9, STABILITY TYPE   STB.

This is a single-character input. The Pasquill categories are identified as A through F; the U option will cause the program to request the diffusion parameters; S will select the Pasquill category from additional data; and W will select from a table of diffusion rates for different types of woods. The logic of the stability selection and the table of woods parameters are given in Appendix A.

STB Code	Atmospheric Stability (Pasquill) (STB)
A unstable	
B	
C	Pasquill Stability Categories
D	
E	
F stable	
U	Undefined. Used when ALF, SYR, BTA, SZR are input.
S	Select stability from meteorological observations
W	Wooded areas

3.10   Question 10, WIND SPEED (m/sec)   WND.

The transport wind speed is entered in meters per second as indicated. Other units, such as knots or miles per hour, may be used if the number is preceded with the proper two-character code. The list of codes may be displayed by typing two question marks.

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When the WOODS option is specified for stability, the wind speed is input for a height of 10 meters. The speed is converted by the program to the expected below canopy rate. In order to enter the below canopy rate directly, the number is entered as negative.

3.11 Question 11, ALF, SYR (m), BTA, SZR (m).

The diffusion parameters for the sigma y and sigma z distributions are requested when the U option is specified for stability. The variable ALF is the slope of log sigma y versus log distance, and 3TA is the slope for log sigma z versus log distance. The reference values SYR and SZR are taken at 100 meters.

3.12 Question 12, TEMPERATURE (°C).

For instantaneous release of HD and when the EVP release option is used, question 12 is preceded by the word SURFACE. This indicates that the temperature specified should be the temperature of the liquid surface. Other releases that request temperature employ the air temperature. (When the temperature is not requested, the number printed with temperature in the output summary has no effect on the prediction).

3.13 Question 13, Q () (mg), QT () (min)   NQI.

Question 13 is provided to input source time increments (that is the quantity released and the time over which the release was made.) This form is used for all types of release except instantaneous and evaporative. For semi-continuous release (SEM), one time interval is implied and does not have to be entered. For the remaining releases, the number of intervals, NQI, is requested. From one to six intervals may be defined. This is followed by one Q and TQ pair for each (maximum of 6). The quantity, Q, is the amount released in that interval, and the time is cumulative as measured from the beginning of the first interval.

3.14 Question 14, MOLECULAR WEIGHT   FMW.

If the substance released is not in the agent list given above (Section 3.6) and the molecular weight enters into the calculation, this will be requested here.

3.15 Question 15, ALL OTHER INPUT.

Although not otherwise specified, the ALL question is 15th in sequence. The other questions are numbered so that the operator may refer to a specific question with control statements. These statements are INP, GTO, and IRT as listed in Table 1 above. The GTO option will initiate a rescan and stop for input at the question specified. Any other questions defined by IMP will also stop for input. The IRT option is like GTO except that it is repeated automatically at the end of each execution. Once set, this is cleared by setting the question to zero (IRT 0).

The assessment controls IMA, 2MC, MNR, and the output, OPO, are all set to default values as indicated in Table 2. If other options are required,

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these should be set at this time. Options IMA, NOV, and OPO will remain as set until another option is given. Options 2MC and MNR are reset to the default values on rescan unless a hold is placed on each (HLD 2MC or HLD MNR). The command DSP with a question number will display the options and definitions for that question.

3.16   Question 16, ATMOSPHERIC PRESSURE (mm Hg)   PMM.

The atmospheric pressure is requested, when needed, if the standard site has not been defined. The pressure for a standard site may be changed in the ALL question. To keep this value, a hold should be placed on PMM (HLD PMM).

3.17   Question 17, SURFACE CODE   SUR.

Surface codes for gravel (GRA) and concrete (NPR) are provided that will make a rough estimate of the puddle size that would be formed on level terrain. The NDF option permits the wetted area to be input.

3.18   Question 18, TIME OF EVAPORATION (min)   TIM.

This is the time of evaporation. If the time given is greater than the time required for total evaporation, the time is reset by the program.

3.19   Question 19, AREA OF THE WETTED SURFACE (sq m)   ARE.

If the surface code is given as NDF, the area of the puddle will be requested.

3.20   Question 20, LENGTH OF SURFACE DOWNWIND (m)   LEN.

This is the estimated fetch of the vapor over the wetted surface of the puddle.

3.21   Question 21, FMW, FMV, VAP (mm Hg), BPT (deg K).

If the physical constants are not available in the data base, the molecular weight, molecular volume, vapor pressure (at the temperature of interest), and boiling point are requested.

3.22   Question 22, TIME AFTER FUNCTIONING   TIM.

This question is asked only for explosive release of HD from a standard round. The time is the lapsed time from functioning to the time the cumulative dosage is measured.

3.23   Question 23, OUTPUT CODE   OPC.

One of the output options listed under OPC in Table 4 is entered here. These options refer only to the output when the plume rise options STK and STJ are specified. These options control what is displayed but also control whether the cloud is traced with distance (f(x)) or is assumed to rise as one step above the stack.

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3.24   <u>Question 24, HEIGHT OF STACK (m)   HST.</u>

3.25   <u>Question 25, DIAMETER OF STACK (m)   DST.</u>

3.26   <u>Question 26, TEMPERATURE OF STACK (deg C)   TST.</u>

3.27   <u>Question 27, VELOCITY OF EFFLUENT (m/sec)   VST.</u>

3.28   <u>Question 28, RELATIVE DENSITY OF EFFLUENT   RDE.</u>

3.29   <u>Question 29, FROST PROFILE EXPONENT   FRO.</u>

        This is the log-log slope of the wind profile.

3.30   <u>Question 30, HEAT RELEASED (cal)   HRL.</u>

3.31   <u>Question 31, CLOUD RADIUS (m)   CRD.</u>

3.32   <u>Question 32, STATION LATITUDE and LONGITUDE (deg)   SLA and SLO.</u>

3.33   <u>Question 33, MONTH, DAY, HOUR   IMM, IDD, and HRS.</u>

        The first three letters of the month, the day as two digits, and the standard military time as four digits are entered here (JAN,01,1200). The output of the month will be displayed as a numeric (1-12) and, if the month is changed in the ALL statement, it is entered as a numeric (IMM 4). The first time the S option is used for stability the program will request the year. This is done to compute the vernal equinox for the year specified.

3.34   <u>Question 34, CLOUD COVER (1/10), CLOUD HEIGHT (ft)   CCT and CHT.</u>

        This is the number of tenths of coverage (overcast = 10) and the cloud height in <u>feet</u>.

3.35   <u>Question 35, SUN ELEVATION ANGLE (deg)   SUN.</u>

        This is entered as degrees above the horizon.

3.36   <u>Question 36, WOODS TYPE   WOO.</u>

        This is entered as a two-digit code as defined in the following table:

                WOO = DW   Deciduous, winter
                      MW   Mixed, winter
                      CF   Coniferous forest
                      MS   Mixed, summer
                      RF   Rain forest

4.   DISCUSSION

4.1   <u>Program Input Rescan.</u>

        When the program forms its first input string of questions, it may copy data on munitions, agents, and locations from tables for input to the

downwind distance calculator (DDS or CDS). Also the EVAP, STAB, or WOODS subroutines may be called in this process. Once the program has executed and returned to "ALL OTHER INPUT" (question 15), all of these values are retained and the same problem would be rerun if the word ALL is input again at this point.

The RST option will reinitialize the program and establish a new input string for the next run. However, if the next run is similar to the first, the user can take advantage of the data already present and input only the changes. These changes can include any of the variables listed in Table 4.

Many of these variables will affect the data copied from the tables in the first scan and thus a rescan of the input phase is needed. The variables that may require input rescan are listed below.

AGN	DOW	IMM	PMM	SLO	TIM
ARE	FMV	INP	QQQ	STB	TMP
BPT	FMW	LOC	REL	SUN	VAP
CCT	HRS	MUN	SEA	SUR	WND
CHT	IDD	NMU	SLA	TEV	WOO

4.2 Rescan and the HLD Command.

Although the automatic table look-up feature is designed to aid the user, there are conflicts that must be understood. The table look-up is repeated with each rescan. Thus, a variable value can be stored in the ALL statement but, if the combination of inputs causes the input rescan, the value may be overwritten by a value from the tables. See Section 2.2 and 3.15 for further discussion.

4.3 Concentration Options.

The downwind concentration, CDS, is selected when values of 1, 2, or 3 are assigned to IMA in the ALL question. When any of these values of IMA are input, a message (DEFINE NCI) will be printed. This is to remind the user that the concentrations of interest must be specified since there are no tabular values for concentration. When a value is assigned to NCI, the instruction INPUT: CI()S will be printed. The values of CI should be in ascending order and the number of entries must agree with NCI. If NCI is not defined, the program will use any numbers left from a dosage run as if they were concentrations, or the program will return to ALL as explained in Section 4.4 if no dosage has been defined.

When concentration is selected by setting IMA to 1, 2, or 3, the program automatically places a hold on NCI to prevent the rescan procedure from overwriting the concentrations of interest with the tabular dosages. This hold is released when IMA is again set to zero. (A hold on either NDI or NCI will bypass the table lookup for dosages of interest.)

4.4 DEFINE NDI or NC$_i$.

If the program attempts to enter the downwind distance calculators (DDS or CDS) without a defined dosage or concentration of interest, the demand DEFINE NDI or DEFINE NCI is printed and control returned to the ALL statement.

4.5   Multiple Munitions.

If a calculation is being made for two or more munitions functioning or being spilled at the same location, the source strength can be increased in unit multiples by assigning a number to NMU in the ALL statement. This approach, of course, assumes that all munitions are the same and that agent is released in the same manner. Thus, the scenario for a pallet of M55 rockets will still require two runs, one for the munitions that function and one for those that leak. However, the number of munitions in each release may be entered directly as NMU. Although NMU is displayed as an integer, the value may be entered as a real number or fraction. In this manner, adjustments may be made for partial spills or partial releases. When there is no fractional part, NMU is displayed in the header as an integer. When there is a fractional part, the header will list numbers less than 10 and greater than .009 with two decimal digits.

4.6   Wind Speed in Woods.

The meteorological parameters given in DODESB TP No. 10 for wooded areas indicate a reference wind speed outside the woods as well as the transport wind within the woods. The program is designed to convert from reference (outside) to transport (inside) so that the normal input would be the reference wind speed. However, provisions are made to enter the transport speed directly if this is known. This signal to the program is to specify the wind speed as negative. Thus, if you wish to specify the in-woods wind speed, enter the number as negative.

4.7   Units Conversion.

Subroutine UNT permits the conversion of units for many of the variables. The system is designed to be invisible to the user who enters the conventional metric units requested. When "strange" units are used, the first two characters of the space that would normally be numeric are replaced with two alpha characters that identify the input. This system is operable on all input questions that contain only one numeric variable. The units that may be converted and the two character codes that will initiate this change are given in the following table:

UNIT CODES

ATM = AT	SQ FT = SF	LB = LB	MB = MB	GAL = GL
BAR = BR	GM = GM	M = MT	OZ = OZ	L = LT
CM = CM	HR = HR	M/MIN = PM	SEC = SC	ML = ML
DEG F = DF	IN = IN	C M/MIN = M3	TON(L) = TL	PT = PT
FT = FT	KT = KT	MI/HR = MH	TON = TN	QT = QT

It should be noted that the questions in which the units can be converted include question 15 (the ALL question). Thus, the variables that appear in the "multi-numeric" questions, which cannot be converted directly, may still be converted in the ALL question by reentering the variable name, a space or comma, the two-character conversion code, and the numeric value in the "strange" units.

Whenever the units conversion function is employed, the program will list the input units, the output units, and the converted numeric value. If

meters are input as the conversion code (MT), this will be converted to feet. The only place where this conversion is appropriate would be in the conversion of cloud height, if it were known in meters. There is no internal check to assure that the conversion is appropriate for the variable. It is thus the responsibility of the user to assure that the final units agree with the input requested. Conversion errors may be corrected by repeating the input in the ALL question.

If question marks are entered for the conversion code or an undefined code is used, the units code table given above will be listed. The program will then repeat the input question. For the ALL question, no variable name is listed but control remains in the ALL loop so that the variable may be re-entered on the next cycle.

The last five unit codes (Gal, l, ml, pt, qt) are measures of volume. These are converted to weights by using the density of the substances. The densities are stored for the 17 substances in the agent list. For other substances the program will request the density.

4.8   Calculations During Input.

When the EVP option of release is used, the EVAP3 subroutine is called during input to compute the airborne source. Each time this subroutine is executed, two lines are output to summarize the results. The surface code is listed and then values of the following:

EVP   Evaporation rate from puddle (mg/min-sq m)
AREA   Area of puddle (sq m)
VPR   Vapor pressure of liquid (mm Hg)
Q   Initial quantity spilled (mg)
Q'   Airborne source (mg)
TEV   Time of evaporation (min)

One line is output each time the stability selector is called. The computed values are as follows:

SR   Sunrise (standard military time)
SS   Sunset
AE   Elevation angle of sun above the horizon (deg)
STAB   Stability category

4.9   Igloo Fires.

Subroutine IGL has been added to D2PC programs released after June 1986. This subroutine contains the unit-weighting factors for the igloo fire scenario for the M55 containing either GB or VX. The subroutine is called by specifying the method of release as IGL. The number of rounds is specified with NMU in the ALL statement. The program will display the three release intervals employed for GB and the single interval used with VX.

4.10   Still Air Evaporation.

In program D2 and in the early version of D2PC, the still air evapo-
ration option could be called only by specifying a small wind speed. In the
version released after June 1986, a release option, EVS, has been added to
treat a spill within an enclosure where the vapor would then escape to the
outside. When EVS is specified, the still air model is used to determine the
amount that evaporates within the enclosure, but the wind speed specified by
the user is then used to compute the downwind travel and dosage. This avoids
having to run the program first as an evaporation source with a small wind
speed to determine the source and then again, as a semicontinuous source with
the outside wind speed to determine the transport.

5.   ERROR MESSAGES

Most of the error messages are self explanatory. A few refer back to
the methodology and some additional comments are given below.

CON NOT DEF FOR INS VX HD - Concentration not defined for instanta-
neous release of VX or HD. This message is produced when the concentration
model is requested (IMA = 1) with instantaneous release of VX or HD from a
munition. The models for this combination that are contained in the program
are designed for dose or dosage only. Concentrations can be computed by pro-
viding the amount airborne and specifying a nonmunition (NON).

DEFINE HML - Define the height of the mixing layer. This message
occurs when the table look-up has not defined a value for HML.

DEFINE NCI - A reminder that the number of concentrations of interest
must be defined

DEFINE NDI - A reminder that the number of dosages of interest must be
defined

DEFINE NQI - A reminder that Q is changed by defining NQI

DHJ NOTE: UNSTABLE MET CONDITIONS - Jet plume note: Unstable meteo-
rological conditions. This a reminder that the jet plume model proposed by
Briggs-Thomas is limited to stable and neutral conditions.

DHS NOTE: VS/UZ LT 4 - Jet plume note: The stack velocity divided by
the wind speed is less than 4. The model is derived for greater than 4.

DHH/DHB/DHBT Note: STK TMP LESS THAN AIR TMP - Note for Holland,
Briggs, and Briggs-Thomas plume models: Stack temperature is less than air
temperature. A reminder that the models are derived for a positive difference
$(T_s - T_a)$.

FUMIGATION - A reminder that the fumigation equation has been used
(Equation 66, Appendix A). It should be noted that the distance computed by
this model is not the distance from the initial source but the distance from
the cloud at the time the ground level inversion breaks up.

HEIGHT DEFINED FOR STABLE CONDITIONS ONLY - A reminder that the model applies only for neutral and stable conditions

MUNITION-AGENT NOT DEFINED - This message occurs when the combination given is not in the standard table.

Q' EQ ZERO - The airborne sources, Q', is zero. Control returns to the ALL statement.

STILL AIR - This message is a reminder that the still air model for evaporation has been used.

TMP GREATER THAN BOILING POINT - Temperature greater than boiling point of liquid. The program will continue with the total amount spilled as the airborne source.

TMP LESS THAN FREEZING - Temperature less than freezing. Q' is set to zero and control is returned to the ALL statement.

6.   OUTPUT

Output is controlled by the three variables NOV, OPO, and OPC, which are defined in Table 3. The options for NOV were discussed in Section 3.1. The long listing displayed when NOV equals 2 or 3 will become tedious after the user has gained some experience with the program. A shift to one is recommended as soon as the options can be recognized by the operator.

During execution the first line of output comes from the MASTER program and is essentially a summary of the input information. The next two lines come from subroutine DDS and list the source (Q), the release time (TS), the release height (HTS), the height of the mixing layer (HML), and the source sigmas (SXS, SYS, SZS). When the default value of OPO is used, the program will execute and list the distance to each of the three response levels, 1 percent lethality, no deaths, and no effects. If other dosages are specified by the operator, these dosages will be listed with each estimated distance.

When the 2-minute correction is used with estimates for nerve agents, an extra header line (w/2-min correction) is displayed; when this correction is dropped, a (w/o 2-min correction) line is shown.

Options 1 and 2 will also cause the diffusion parameters to be listed as lines 4 and 5. These lines will also list XY and XZ, which are the offset distances for sigma -y and sigma -z that are given in the methodology as parameters B and C. The last output at the end of line 5 (OPO = 1 or 2) is the wind speed used in the calculation. This may differ from the wind speed given in the first line when the woods parameters are selected.

The following is a list of definitions for the output under options 1 and 2:

$$X \qquad \text{Downwind distance (m)}$$
$$DP \qquad \text{Peak dosage (mg min/m}^3)$$

DP2 Peak dosage with 2-minute correction
ED Effective dosage (mg min/m^3)
ED2 Effective dosage with 2-minute correction
RF Fraction reflected from mixing layer
2MF Two-minute correction factor
EDI Inhalation component of ED2
EDS Skin deposition component of ED2

When OPO option 3 is used, a header is printed for the contour dosages and then the contour half-widths.

7. SUMMATION OF DOSAGE DISTRIBUTION

   A provision has been made to sum the dosage at each downwind distance so that the hazard distance from multiple sources may be output directly. This process, of course, is limited to sources of the same agent.

   To utilize this feature, three control commands have been added to the ALL question:

     SMC Clear sum D(X)
     SMD Add current D(X) to sum D(X)
     SMP Print X(DI) from sum D(X) plus current D(X)

   Sum D(X) and current D(X) are each 51 element tables that store the dosage for each distance and thus define the downwind distribution. With each run, the dosages generated are stored as the current D(X).

   The sum D(X) table will initially be cleared to zero and, if the SMD command is executed, this will store the current D(X) values in the sum D(X) table. After the changes for the next distribution have been input, the next run will generate and store a new current D(X), leaving the previous values stored by SMD in the sum D(X) table.

   If the downwind distances are to be based on the sum of these two distributions, the second run should be preceded with the command SMP, which will tell the program to add the value in the sum D(X) table to the current value in estimating the distance. The SMP command does not change the values stored in either table.

   Repeated use of the SMD command will continue to add the dosages in the current D(X) table into the sum D(X) table. The sum D(X) table is cleared with the command SMC.

   Thus, the sum D(X) table is controlled by SMC and SMD, and the current D(X) table is changed only by executing a new run. When a run is preceded by SMP, the downwind distance will be based on the current D(X) plus the sum D(X) values. The SMP command is cleared each time the program gets to the ALL question, so the SMP command must be repeated if the command is given before a rescan.

   The user is cautioned to assure that the dosages from the previous run extend beyond the dosages of interest in the final run. For example, if the

first run is terminated at the 1 percent distance, then the dosage will only be stored to the next regular distance. If the sum would extend the curve beyond this distance, then the remaining portion of the first curve will be missing and the answer would be incorrect.

The recommended procedure is to define a small cutoff dosage for the first run using NDI in the ALL question. In this manner the dosages will be stored beyond the distance estimated with the sum. The storage table for the dosages is dimensioned at 51 and thus can store dosages to a distance of 900 km.

In operation, the current D(X) table always retains the dosages of the last run. The SMD command does not clear (or change) the current D(X) table. The SMP command leaves the current D(X) table with the last component generated. This is not the sum on which the distances are based. This component can be regenerated and printed (OPO = 1) by repeating the run without the SMP command.

In this version of D2PC, the intravenous doses that were output for VX deposition are converted to effective dosages so that these can be added directly in the summation process. These are converted for a breathing rate of 25 1/min. If another rate is needed, the breathing rate, BRT, should be changed in the ALL question.

8.   VAPOR DEPLETION

In response to a request from the U.S. Army Toxic and Hazardous Materials Agency (THAMA), a vapor depletion option has been written into the program. (This was done to support Oakridge National Laboratory in their support of the M55 demilitarization effort.)

The approach chosen is based on the current open literature and has not as yet been reviewed or approved as a part of TP 10 by the DOD Explosive Safety Board.

The vapor depletion option is controlled by the indicator VDP, which can be defined in the ALL question. Vapor depletion is called by setting VDP to one and is released by setting it to zero. (The default value is zero.)

The vapor depletion is computed as a reduction of the source strength by computing the mass of vapor that would have been lost to the distance of interest. This is done by computing a deposition velocity as a function of wind speed, stability, and roughness length and then multiplying this by the integrated area-dosage (or area-concentration) to the point of interest. The fraction remaining is listed before each downwind estimate. Comments on the computer implementation of this process are given in Appendix B. The methodology is presented, along with the source references, in Appendix C.

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APPENDIX A

METHODOLOGY

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APPENDIX A

METHODOLOGY

1.   INTRODUCTION

This appendix presents the methodology for the atmospheric diffusion, plume rise, and liquid evaporation employed in this program. The diffusion methodology is limited to estimating the axial dosage or concentration at ground level. This restriction is appropriate for hazard distance estimates.

2.   TOTAL DOSAGE MODELS

The basic equation for computing the axial dosage from a point or virtual point source is given by

$$D(x) = \frac{Q}{60\pi\sigma_y\sigma_z U} \left[e^{-1/2 (H/\sigma_z)^2} + \sum_{i=1}^{\infty} \left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2} \right) \right] \quad (A-1)$$

where

$D(x)$ = axial dosage at the point x downwind (mg min/m^3),

Q = source strength (mg),

σ_y or $\sigma_y(x)$ = standard deviation of crosswind concentration at x (m),

σ_z or $\sigma_z(x)$ = standard deviation of vertical concentration at x (m),

U = mean wind speed (m/sec),

H_m = height of the surface mixing layer (m),

H = effective height of the source (m).

The standard deviations, $\sigma_y(x)$ or $\sigma_z(x)$, or σ_z, are computed for the appropriate distance, x, as follows:

$$\sigma_y(x) = \sigma_{yr} \left(\frac{x + B}{x_{yr}} \right)^{\alpha} \quad (A-2)$$

$$\sigma_z(x) = \sigma_{zr} \left(\frac{x + C}{x_{zr}} \right)^{\beta} \quad (A-3)$$

where

σ_{yr}, σ_{zr} = reference sigma values at the distances x_{yr}, x_{zr}, respectively (m),

x_{yr}, x_{zr} = reference distances (100 m),

α = expansion coefficient in the crosswind direction (dimensionless),

β = expansion coefficent in the vertical (dimensionless),

B = virtual distance calculated for volume source (m)

$$= x_{yr}\left(\frac{\sigma_{ys}}{\sigma_{yr}}\right)^{1/\alpha}$$

σ_{ys} = standard deviation of initial source in the crosswind direction (m),

C = virtual distance calculated for volume source (m)

$$= x_{zr}\left(\frac{\sigma_{zs}}{\sigma_{zr}}\right)^{1/\beta}$$

σ_{zs} = standard deviation of initial source in vertical (m).

The basic total dosage model simplifies somewhat when the clouds become trapped under a mixing layer cap and eventually result in a cloud with a uniform distribution of concentration in the vertical. Mathematically, this occurs as the infinite series

$$e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)$$

approaches

$$\sqrt{\frac{\pi}{2}} \cdot \frac{\sigma_z}{H_m}$$

for sufficiently large x. This new formulation of the total dosage model

$$D(x) = \frac{Q}{60\sqrt{2\pi}\sigma_y H_m U} \tag{A-4}$$

is commonly called the "box model."

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When the initial source is uniform over a line of finite length, L, in the crosswind direction (y), the ground level total dosage along the cloud's axis (the line starting at the midpoint of L in the direction of the wind) is given by

$$D(x) = \frac{\sqrt{2}\,Q}{60\sqrt{\pi}L\sigma_z U}\left(\text{erf}\left(\frac{L}{2\sqrt{2}\sigma_y}\right)\right) \cdot \left[e^{-1/2(H/\sigma_z)^2} + \right.$$

$$\left. \sum\left(e^{-1/2((21H_m + H)/\sigma_z)^2} + e^{-1/2((21H_m - H)/\sigma_z)2}\right)\right] \qquad \text{(A-5)}$$

where

$\qquad$ L = line length (m),

$\qquad$ erf (v) = error function evaluated at v

$$\qquad = \frac{2}{\sqrt{\pi}}\int_0^v e^{-w^2}\,dw.$$

All others as defined above.

3.	DIFFUSION PARAMETERS

The set of diffusion parameters used in the derivation of the tables and graphs presented in this handbook was taken directly from Technical Paper No. 10.[1] Table A-1 gives the required reference sigmas and expansion coefficients.

Table A-1. Recommended Values of Parameters

$(x_{yr} = x_{zr} = 100\ m)$

Stability category	σ_{yr} (2.5 sec) (m)	σ_{yr} (10 min) (m)	σ_{zr} (m)	α	β
A	9.0	27.0	14.0	1.0	1.4
B	6.33	19.0	11.0	1.0	1.0
C	4.8	12.5	7.5	1.0	0.9
D	4.0	8.0	4.5	0.9	0.85
E	3.0	6.0	3.5	0.8	0.8
F	2.0	4.0	2.5	0.7	0.75

4. TWO-MINUTE CORRECTION MODEL

This methodology[2] is required to implement the changes in effective dosages of GB and VX as a function of exposure time in agent clouds of nonuniform concentration. Since dosage is a function of exposure time, the degree of hazard will be reduced in those accidents where the vapors are evolved slowly over a substantial time as compared with nearly instantaneous releases. This is a result of a nonlinear relationship between dosage, exposure time, and the expected physiological response.

The basic model for calculating ground level partial dosages is as follows:

$$D(x;\Delta\theta) = \frac{Q}{60\pi\sigma_y\sigma_z U} \left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty} \left(e^{-1/2((2iH_m + H)/\sigma_z)^2} \right. \right.$$

$$\left. \left. + e^{-1/2((2iH_m - H)/\sigma_z)^2} \right) \right] \; 1/2 \left[\mathrm{erf}\left(\frac{x - U\theta_1}{\sqrt{2}\sigma_x} \right) - \mathrm{erf}\left(\frac{x - U\theta_2}{\sqrt{2}\sigma_x} \right) \right] \quad (A-6)$$

where

$\Delta\theta$ = time interval of interest (min),

$= \theta_2 - \theta_1$,

θ_1, θ_2 = beginning and end of time interval as measured from the release time,

σ_x or $\sigma_x(x)$ = standard deviation of the concentration in the x direction (m).

All others as defined above.

For an instantaneous source, dosage buildup at a point as a function of time is readily determined from equation A-6. For releases occurring at a uniform rate, $\Delta Q/\Delta t$, for a time period from the initiation of emission, $\theta_0(=0)$ to θ_s, computation of the dosage for an arbitrary interval, $\Delta\theta = \theta_2 - \theta_1$, requires application of the more complicated expressions:

$$D(x;\Delta\theta) = K(T_5 - T_2 + T_4) \qquad \text{for } \theta_s > \theta_2 > \theta_1$$

$$D(x;\Delta\theta) = K(T_1 - T_2 - T_3 + T_4) \qquad \text{for } \theta_2 > \theta_1 > \theta_s \qquad (A-7)$$

where

$$K = \frac{\Delta Q/\Delta t}{3600 \cdot 2\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right]$$

$$T_1 = (\theta_2 - \theta_s - x/u)\,\text{erf}\left\{\frac{x - u(\theta_2 - \theta_s)}{\sqrt{2}\sigma_x}\right\} - (\theta_1 - \theta_s - x/u)\,\text{erf}\left\{\frac{x - u(\theta_1 - \theta_s)}{\sqrt{2}\sigma_x}\right\}$$

$$T_2 = (\theta_2 - x/u)\,\text{erf}\left\{\frac{x - u\theta_2}{\sqrt{2}\sigma_x}\right\} - (\theta_1 - x/u)\,\text{erf}\left\{\frac{x - u\theta_1}{\sqrt{2}\sigma_x}\right\}$$

$$T_3 = \frac{\sqrt{2}\sigma_x}{\sqrt{\pi}u}\left[\exp\; -\left\{\frac{(x - u(\theta_2 - \theta_s))^2}{2\sigma_x^2}\right\} - \exp\; -\left\{\frac{(x - u(\theta_1 - \theta_s))^2}{2\sigma_x^2}\right\}\right]$$

$$T_4 = \left[\frac{\sqrt{2}\sigma_x}{\sqrt{\pi}u}\;\exp\; -\left\{\frac{(x - u\theta_2)^2}{2\sigma_x^2}\right\} - \exp\; -\left\{\frac{(x - u\theta_1)^2}{2\sigma_x^2}\right\}\right]$$

$$T_5 = (\theta_2 - \theta_1)\,\text{erf}\left\{\frac{x}{\sqrt{2}\sigma_x}\right\}$$

If $\theta_1 < \theta_s < \theta_2$, the total time period is partitioned into the segments θ_1 to θ_s and θ_s to θ_2. The dosage contribution for each time segment is derived separately from the appropriate form of the equation and the results added. Equation A-6 is also readily adapted to cases of variable rate of agent generation, provided the total emission time can be divided into a set of intervals for each, where a constant $\Delta Q/\Delta t$ can be assumed. The contribution of a "source segment," as defined by $\Delta Q/\Delta t$ over a given time interval, to the total dosage accumulated during $\Delta\theta$ may be computed independently for each such segment from equation A-6.* The sum over the set of values so obtained is the total dosage of interest.

*In applying equation A-6, it should be noted that agent emission is defined in the expressions as occurring from the origin ($\theta_0 = 0$) of the time scale to θ_s. For cases involving a series of uniform generation rates, appropriate translations of the time scale (i.e., agent emission from θ_a to θ_b) will be necessary.

The expansions for σ_y and σ_z are noted in section 2 of this appendix.

Values for σ_x may be computed from a study of long-distance cloud travel, which was done by Halvey* in 1973. This work resulted in the following relationship:

$$\sigma_x = .1522 \, x^{.9294}$$

It follows from the dosage response curves[2] that an effective dosage for an exposure time t (expressed in minutes) can be obtained by multiplying the corresponding reference "2-minute" value by the factor

$$M = 0.827 \, t^{0.274} \quad (t > 2 \text{ minutes}). \tag{A-8}$$

A rationale was developed for the computation of the multiplier M by means of a numerical procedure that allows for discrete changes in agent concentration as the cloud moves over a ground location. In essence, a "pseudo" exposure time is determined through a sequence of adjustments for successive time increments covering cloud passage. This "pseudo" exposure time, which must be 2 minutes or greater for equation A-7 to be applicable, can be considered essentially as an integrated average. The precise sequential mathematical procedure is as follows:

let

t_i = clock time in minutes,

τ_i = "pseudo" exposure time in minutes,

ΔD_i = dosage accumulation in interval i,

D_i = cumulative dosage to time t_i,

D_{0i} = 2-minute reference dosage.

Subscript m denotes the value computed from transport and diffusion mode.

Subscript e denotes the extrapolated value as indicated below:

<u>1st Interval</u>: Select clock time interval $t_0 \longrightarrow (t_1 - t_0) > 2$ minutes

    a. Determine D_{1m} for interval $t_1 - t_0$ from transport and diffusion model,

    b. Set $\tau_1 = t_1 - t_0$,

*Halvey, David D. Estimation of Cloud Length for Long Distance Travel. Unpublished data, Operations Research Group, Egewood Arsenal, Maryland, July 1973. UNCLASSIFIED.

c.   Compute.

$$D_{01} = \frac{D_{1m}}{(0.827)(\tau_1)^{0.274}}$$

2d Interval: Select clock time interval $t_1 \longrightarrow t_2$

a.   Determine ΔD_{2m} for interval $t_2 - t_1$ from transport and diffusion model.

b.   Compute   (1) $D_{2m} = D_{1m} + \Delta D_{2m}$,

(2) $D_{2e} = 0.827\, D_{01}\, (\tau_1 + t_2 - t_1)^{0.274} - (\tau_1)^{0.274}$,

c.   Compare ΔD_{2m} with ΔD_{2e}

(1)   If $\Delta D_{2m} = \Delta D_{2e}$, set $\tau_2 = \tau_1 + t_2 - t_1$,

(2)   If $\Delta D_{2m} > \Delta D_{2e}$, compute

(a) $D_{2e} = D_{1m} + \Delta D_{2e}$

(b) $\tau_2 = \left[\dfrac{D_{2e}(\tau_1 + t_2 - t_1)^{0.274} + (\Delta D_{2m} - \Delta D_{2e})(t_2 - t_1)^{0.274}}{D_{2m}} \right]^{\frac{1}{0.274}}$

(3)   If $\Delta D_{2m} < \Delta D_{2e}$, compute

$$\tau_2 = \left[\frac{\dfrac{\Delta D_{2m}}{t_2 - t_1}(t_2 - t_0)(\tau_1 + t_2 - t_1)^{0.274} + \left[D_{1m} - \dfrac{\Delta D_{2m}}{t_2 - t_1}(t_1 - t_0) \right]\tau_1^{0.274}}{D_{2m}} \right]^{\frac{1}{0.274}}$$

d.   Compute $D_{02} = \dfrac{D_{2m}}{0.827(\tau_2)^{0.274}}$.

General Case: Select clock time interval $t_{i-1} - \longrightarrow t_i$

a.   Determine Δd_{im} for interval $t_i - t_{i-1}$ from transport and diffusion model,

b. Compute

(1) $\quad D_{im} = D_{(i-1)m} + \Delta D_{im}$,

(2) $\quad \Delta D_{ie} = 0.827\, D_{0(i-1)} \left[\left(\tau_{i-1} + t_i - t_{i-1} \right)^{0.274} - \left(\tau_{i-1} \right)^{0.274} \right]$

c. Compare ΔD_{im} with ΔD_{ie}

(1) $\quad$ If $\Delta D_{im} = \Delta D_{ie}$ set $\tau_i = \tau_{i-1} + t_i - t_{i-1}$,

(2) $\quad$ If $\Delta D_{im} > \Delta D_{ie}$, compute

(a) $\quad D_{ie} = D_{(i-1)m} + \Delta D_{ie}$

(b) $\quad \tau_i = \left[\dfrac{D_{ie}\left(\tau_{i-1} + t_i - t_{i-1} \right)^{0.274} + \left(\Delta D_{im} - \Delta D_{ie} \right)\left(t_i - t_{i-1} \right)^{0.274}}{D_{im}} \right]^{\frac{1}{0.274}}$

(3) $\quad$ If $D_{im} < D_{ie}$, compute

$$\tau_i = \left[\dfrac{\dfrac{\Delta D_{im}}{t_i - t_{i-1}}\left(t_i - t_0 \right)\left(\tau_{i-1} + t_i - t_{i-1} \right)^{0.274} + \left[D_{(i-1)m} - \dfrac{\Delta D_{im}}{t_i - t_{i-1}}\left(t_{i-1} - t_0 \right) \right]\tau_{i-1}^{0.274}}{D_{im}} \right]^{\frac{1}{0.274}}$$

d. Compute $D_{0i} = \dfrac{D_{im}}{0.827\left(\tau_i \right)^{0.274}}$.

For n increments, the reference 2-minute dosage D_{0n} is the value used in constructing the generalized curves for GB and VX respiratory effects.

In using the above procedure, three precautions must be observed. Firstly, τ_i cannot be permitted to decrease below 2 minutes. Although such occurrence would generally be unlikely, the possibility should be recognized in the computational procedure. Secondly, D_{0i} must be nondecreasing for successive increments. If $D_{0(k+1)} < D_{0k}$, as could occur through consideration of very low dosages produced by the trailing edge of a cloud over an extended time period, it is recommended that $D_{0(k+1)}$ be set equal to D_{0k} before proceeding to the next interval. Thirdly, since it is not apparent that the maximum value of D_{0i} will always exceed the actual peak 2-minute accumulation during cloud passage, a numerical comparison should be made, with the larger value obviously accepted as the basis for hazard-distance estimation.

5.   CONCENTRATION MODELS

The mathematical model representing the maximum ground level concentration from an instantaneous point or virtual point source at a distance x is given by

$$\chi(x) = \frac{Q}{\sqrt{2\pi}^{3/2}\sigma_x\sigma_y\sigma_z}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \quad (A-9)$$

where

$$\chi(x) = \text{concentration at the point } x \ (mg/m^3).$$

All others as defined above.

For the continuous case, differentiation is made between the purely continuous release and that of the quasi-continuous release. In the purely continuous case, the emission time is assumed to be sufficiently large so that a steady-state concentration is reached at each point downwind. The concentration[3] from a continous point source is numerically equal to the dosage from an instantaneous source whose total emission is numerically equal to the rate of the continous source, $\Delta Q/\Delta t$, thus,

$$\chi(x) = \frac{\Delta Q/\Delta t}{60\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \sum\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \quad (A-10)$$

where

$$\Delta Q/\Delta t = \text{rate of emission } (mg/min).$$

All others as defined above.

For the quasi-continuous releases,[4] the maximum axial concentration at a distance x is given by

$$\chi(x) = \frac{\Delta Q/\Delta t}{60\pi\sigma_y\sigma_z U}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \text{ for } x < X_c,$$

$$\chi(x) = \frac{\Delta Q/\Delta t \ t_s}{\sqrt{2\pi}^{3/2}\sigma_x\sigma_y\sigma_z}\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2} + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right] \text{ for } x > X_c. \quad (A-11)$$

where

$$X_c = \exp\left[\ell n\ \{(t_s \cdot 60 \cdot u)/0.1522 \cdot \sqrt{2\pi}\}/0.9294\right]\ ,$$

$$t_s = \text{release time (min)}.$$

All others as defined above.

For a finite line source, either instantaneous or continuous, where the release is uniform over a line of length, L, in the crosswind direction, the axial concentration is given by

$$\chi(x) = \frac{Q}{L\sigma_x\sigma_z}\ \text{erf}\left(\frac{L}{2\sqrt{2}\sigma_y}\right)\left[e^{-1/2(H/\sigma_z)^2} + \sum_{i=1}^{\infty}\left(e^{-1/2((2iH_m + H)/\sigma_z)^2}\right.\right.$$
$$\left.\left. + e^{-1/2((2iH_m - H)/\sigma_z)^2}\right)\right]$$

(A-12)

when all variables are as defined above.

6.   EVAPORATION MODEL

The evaporation rate model[5] is reproduced here as it was originally presented in ORG report 40.[2] The only change in the methodology has been the conversion to metric units for consistency with this handbook. The procedure is as follows:

Determine the dimensionless Reynold's number, N_{Re} for the airflow from the equation

$$N_{Re} = \lambda \cdot U \cdot \rho\ /\ \mu \times 10^4$$ (A-13)

where

λ = downwind length of the puddle (m),

U = wind speed (m/sec),

ρ = density of the air (gm/cm^3),

μ = viscosity of the air (poise(gm/cm $\cdot$ sec)).

The density of air in gm/cm^3 can be determined by

$$\rho = \frac{0.35232}{T} \cdot P$$ (A-14)

where

$$T = \text{temperature } (°K),$$

$$P = \text{ambient pressure (atm)},$$

The viscosity of air can be determined from

$$\mu = e^{(4.36 + .002844\ T)} \times 10^{-6}. \tag{A-15}$$

From the Reynolds number, calculate the mass transfer factor, J_m, as follows:

$$J_m = 0.664\ N_{Re}^{-0.5} \qquad \text{for } N_{Re} < 20,000$$

$$J_m = 0.036\ N_{Re}^{-0.2} \qquad \text{for } N_{Re} > 20,000 \tag{A-16}$$

With this, the mass transfer coefficient, Kg, is calculated by

$$K_g = G_m \cdot J_m \cdot (\mu/\rho d)^{-2/3} \tag{A-17}$$

where

$$K_g = \text{mass transfer coefficient (gm moles/sec} \cdot \text{cm}^2),$$

$$G_m = \text{molar mass velocity of air (gm moles/sec} \cdot \text{cm}^2),$$

$$(\mu/\rho d) = \text{Schmidt number (dimensionless)},$$

$$d = \text{diffusivity (cm}^2/\text{sec}).$$

The molar mass velocity of air can be determined by the formula

$$G_m = \frac{U \cdot \rho}{M_A} \times 10^2 \tag{A-18}$$

where M_A = molecular weight of air (gm/gm mole).

The diffusivity of air, d, may be computed from

$$d = 0.0043\ \frac{T^{3/2}}{P(V_A^{1/3} + V_L^{1/3})^2} \cdot \left(\frac{1}{M_A} + \frac{1}{M_L}\right)^{1/2} \tag{A-19}$$

where

$$T = \text{temperature } (°K),$$

$$P = \text{ambient pressure (atm)},$$

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V_A = molecular volume of air at normal boiling point $(cm^3/gm\ mole)$,

V_L = molecular volume of liquid at normal boiling point $(cm^3/gm\ mole)$,

M_L = molecular weight of liquid $(gm/gm\ mole)$.

Finally the evaporation rate, E, is defined by

$$E = K_g \cdot M_L \cdot P_L/(760 \cdot P) \cdot 6 \times 10^5 \qquad (A\text{-}20)$$

where

E = evaporation rate of liquid $(gm/m^2\ min)$

P_L = vapor pressure of liquid at liquid air interface (mm Hg).

7.   EVAPORATION RATE INTO STILL AIR

The model for evaporation in still air is reported in change 3 (June 1980) to TP10.[1] This methodology is to be used when the incident occurs within a closed building or other confined location that precludes the movement of air during the evaporation of the toxic liquid. The evaporation rate into still air is calculated using the following semiempirical equation:[6]

$$E_s = 292(1 + 0.51\ Re^{1/2}\ Sc^{1/3})\ \ln\left(\frac{1}{1-P_v}\right)\frac{M_L}{T}\ d\ \frac{\lambda}{2} \qquad (A\text{-}21)$$

where

Es = evaporation rate (gram/min)

R_e = Reynolds number (using a wind speed of .03 m/sec)

Sc = Schmidt number

P = ambient pressure (atmospheres)

P_v = vapor pressure of liquid (atmospheres)

M_L = molecular weight of liquid

T = ambient temperature (°K)

d = diffusivity of air (cm^2/sec)

λ = diameter of spill (meters)

with

$$Re = \frac{0.03 \, \lambda \, \rho}{\mu} \times 10^4 \tag{A-22}$$

ρ = density of vapor (g/cm^3)
μ = viscosity of vapor (g/cm/s)

$$s_c = \frac{\mu}{\rho d} \tag{A-23}$$

In calculating the Reynold's number, the effect of the agent vapor on the air viscosity and density will be ignored.

$$\rho = \frac{.3482}{T} \quad \text{(for water vapor pressure of 25 mm Hg)} \tag{A-24}$$

If the evaporation is into air with a molecular weight of 29 and the liquid has a molecular weight between 27 and 278, then the diffusivity of the liquid's vapor, following the Wilke-Lee equation, can be stated as follows:

$$d = \frac{.00205 T^{3/2} \sqrt{\frac{1}{29} + \frac{1}{M_L}}}{P \sigma^2_{12} \, \Omega_D} \tag{A-25}$$

where

d = diffusivity (cm^2/sec)

$$\sigma_{12} = \frac{\sigma_1 + \sigma_2}{2} = \text{average molecular collision diameter (angstroms)} \tag{A-26}$$

The collision diameter is estimated from the molecular volume as:[6]

$$\sigma = 1.18 \, V_L^{1/3} \tag{A-27}$$

and

Ω_D = collision integral for diffusion

An empirical equation for Ω_D has been developed by Chen[7] as follows:

$$\Omega_D = 1.075 \left(T \frac{\kappa}{\epsilon_{12}}\right)^{-.1615} + 2 \left(10 \frac{\kappa}{\epsilon_{12}} T\right)^{-.74 \log \left(10 \frac{\kappa}{\epsilon_{12}} T\right)} \qquad (A-28)$$

where

$$\frac{\epsilon_{12}}{\kappa} = \sqrt{\left(\frac{\epsilon_1}{\kappa}\right) \cdot \left(\frac{\epsilon_2}{\kappa}\right)} \qquad (A-29)$$

where

κ is the Boltzman constant

ϵ_{12} is the energy of molecular interaction (ergs)

the value of ϵ/κ for the vapor may be estimated by:[6]

$$\epsilon/\kappa = 1.21 \, T_b \qquad (A-30)$$

when T_b is the boiling point of the liquid (°K).

Since ϵ/κ for air is given as 78.6,* the value of $T \epsilon/\kappa_{12}$ in the Chen equation may be estimated as follows:

$$T \frac{\kappa}{\epsilon_{12}} = .1025 \frac{T}{\sqrt{T_b}} \qquad (A-31)$$

8. IMPACTION MODEL

The amount of VX that would impact on a man-sized object as a function of downwind distance and wind speed is estimated as follows[2]:

$$d_p = 0.454 \cdot Q_F \cdot (U/x)^{2.38} \qquad (A-32)$$

where

d_p is the amount deposited (dose per man) (mg)

Q_F is the munition fill weight (mg)

U is the wind speed (m/sec)

x is the downwind distance (m)

9.   VX INHALATION-DEPOSITION

In order to consider the combined effects of aerosol impaction and vapor inhalation as would occur from an exploding VX filled M55, the combined toxicological effects are considered by converting to the intravenous dose d_I. This approach was developed for ORG 40[2] and explained in the handbook.[8] The equation relating the components can be expressed as follows:

$$d_I = D B + d_p F_s \qquad\qquad (A-33)$$

where

d_I is the intravenous dose (mg)

D is the inhaled dosage (mg-min/m^3)

B is the breathing rate (m^3/min)

d_p is the percutaneous dose (mg)

F_s is the skin factor

The inhaled dosage, D, can be computed using Equation 7.

However, if the agent fill weight, Q_F is used as the source, a factor must be introduced to adjust the dosage for the airborne-vapor efficiency of the explosion. An analysis done by Systems Analysis Directorate at ARRCOM, based on tests of the M55 conducted at Dugway Proving Ground, suggests that 13 percent is an appropriate figure. Thus, to compute the intravenous dose from inhalation:

$$DB = D_F . E_v \ B_\ell/1000 \qquad\qquad (A-34)$$

where

DB is the intravenous dose from inhalation (mg)

D_F is the 2-minute computed dosage from Q_F (mg min/m^3)

E_v is the vapor efficiency

B_ℓ is the breathing rate (ℓ/min).

If E_v = 0.13 and B_ℓ = 25 ℓ/min, then:

$$DB = D_F \ 0.00325 \qquad\qquad (A-35)$$

From ORG 40[2] and the handbook,[8] the intravenous dose from deposition on the skin can be computed as follows:

$$d_p \; F_s = 0.455 \; (u/x)^{2.38} F_s \tag{A-36}$$

If $F_s = 0.022$ for light summer clothing,

$$d_p F_s = 0.01 \; (u/x)^{2.38} \tag{A-37}$$

10. HAZARD DISTANCES FOR THE M23 LAND MINE

From an analysis of experimental data conducted by Systems Development Division,[9] the following model was developed to estimate the impaction, or deposition dose, on a man-sized target downwind of a bursting M23 land mine filled with VX. The model is similar to that adopted for the M55 rocket except that the land mine produced very little vapor. Thus, the model for intravenous dose (equation A-33) contains only the deposition component for the M23 mine.

The deposition on a man-sized target is estimated by the following equation:

$$d_p = 0.262 \; Q_F \left(\frac{u}{x}\right)^{2.24} \tag{A-38}$$

where

d_p is the peak deposition dose per man (mg)

Q_F is the fill weight (mg)

u is the wind speed (m/sec),

x is the downwind distance (m)

If one assumes the vapor to be negligible, then

$$d_I = d_p \; F_s \tag{A-39}$$

where

d_I is the intravenous dose (mg)

F_s is the skin factor

The downwind distance may be computed directly from

$$x = u \left(\frac{.262 \; Q_F \; F_s}{d_I}\right)^{.4464} \tag{A-40}$$

or for $Q_F = 5.2E6$, $F_s = .022$, and $d_I = .1$,

$$x = 279 \; u \tag{A-41}$$

Equation A-41 estimates the 1 percent lethality distance with light summer clothing from on bursting M23 mine, filled with VX.

For N mines, the equation is

$$x = 279 \, u \, N^{.4464} \qquad (A-42)$$

11. HD EXPLOSIVE SOURCE

The methodology specified for explosive release of HD (as from the 4.2-inch mortar) in ORG 40[2] and the handbook[8] is not a physical analog in the same sense as the other models. It is a system of factors computed from wind speed, temperature, stability, and time that determines an agent recovery factor, R. This factor is multiplied by the fill weight, Q_F, and the product is used in an empirically fit version of the Gaussian diffusion model to estimate downwind hazard distance.

The tabular-graphic system appearing in the handbook[8] was approximated by a system of equations to permit automation on either a computer (FORTRAN) or a Pocket calculator. These equations are summarized as follows:

$$Q = Q_F R \qquad (A-43)$$

where R is the agent recovery factor

$$R = 1 \qquad \ln F_E < -1.2 \qquad (A-44)$$

$$R_1 = \exp\,(0.365 - 0.862 \ln F_E)$$

$$R = R_1 - \exp\,(-0.248 - 1.14 \ln F_E) \qquad -1.2 < \ln F_E < 0.4$$

$$R = R_1 - \exp\,(-0.0513 - 1.68 \ln F_E) \qquad \ln F_E > 0.4$$

The environmental factor, F_E, is defined by:

$$F_E = F_s \cdot F_W \cdot F_T \, \frac{120}{t_A} \qquad (A-45)$$

where

       F_E is the environmental factor

       F_W is the wind speed factor

       F_T is the temperature factor

       t_A is the lapsed time after detonation (min)

Then

$$F_T = \exp\,(2.2 - 0.0837 \, T_C) \qquad T_C < 27 \qquad (A-46)$$

$$F_T = \exp\,(2.05 - 0.077 \, T_C) \qquad T_C > 27$$

where

$$T_C \text{ is the temperature } (°C)$$

$$F_w = 1.55 \ u^{-0.79} \qquad \text{A-47)}$$

The values of Fs are defined in Table A-2.

Table A-2. Parameters for Explosive HD

Stability	F_S	α, β	SY1	SZ1
A,B	0.7	3.3	0.00000147	0.0000628
C,D	1.0	1.4	0.0108	0.0204
E,F	1.25	1.02	0.0622	0.0636

The dosage at x is then computed from:

$$D(x) = \frac{Q}{60\pi \ \sigma_y(x) \ \sigma_z(x) \ u} \qquad \text{(A-48)}$$

where

$$\sigma_y(x) = \sigma_{y1}(x + B)^{\alpha}$$

$$\sigma_z(x) = \sigma_{z1}(x + C)^{\beta}$$

$$B = (3.8/\sigma_{y1})^{1/\alpha}$$

$$C = (0.2/\sigma_{z1})^{1/\beta} \qquad \text{(A-49)}$$

Equation A-48 is of the same form as equation A-5, except that source sigmas of 3.8 and 0.2 have been introduced. Please note that the values of $\alpha, \beta, \sigma_{y1}$ and σ_{z1} are not the same in Tables A-1 and A-2. The values in Table A-2 are to be used only for explosive HD sources.

12.   PLUMES AND OTHER HEATED SOURCES

This section deals with the techniques involved in the calculation of an effective height of release

$$H = H_s + \Delta h$$

where

H_s is the release height

Δh is the amount of rise due to buoyancy or momentum of a release of agent possessing positive vertical-movement tendencies.

This tendency to rise, either by momentum or buoyancy, creates a pseudo release point at some particular height above the ground and at a distance downwind from the initial release point. The methods presented here are concerned with tracing the centerline as the cloud rises.

Several assumptions are present either explicitly or implicitly in the methods presented. The first is the absence of any major aerodynamic effects present to influence cloud rise. For example, the presence of buildings, topographical features, or the stack itself, in the case of plumes, can create wakes that may result in extremely high concentrations at ground level. A rule of thumb applicable to smoke stacks is that a stack 2.5 times the height of an adjacent building will minimize this phenomenon of downwash.[10] Also, a stack efflux velocity of at least 1.5 times the average wind speed at the top of the stack is usually enough to overcome the downwind pressure gradient creating the downwash effect.[10]

Another assumption is that the height of the mixing layer is greater than the estimate of the effective release height. In situations where this is not the case, the user is directed to Brigg's work,[10] where a methodology is presented for predicting whether a plume can penetrate through the mixing layer cap. In situations where the plume penetrates this cap, the effluent or pollutants are trapped above the surface mixing layer so that only negligible concentrations are expected at ground level.

12.1   Holland Model.

The Holland equation[11] has seen wide use for the determination of plume rise from industrial stacks. This equation frequently underestimates the effective height of the stack and, therefore, provides a slight safety factor in hazard distance calculations. Its major advantage is that each of the variables required is usually easily obtained or estimated. The form of the equation is as follows:

$$\Delta h = \frac{V_s d_s}{U} \left(1.5 + 2.68 \times 10^{-3} \, P_a \, \frac{T_s - T_a}{T_s} \cdot d_s \right) \qquad \text{(A-50)}$$

where

Δh = rise of plume above the stack (m),

V_s = mean stack effluent velocity (m/sec)

d_s = inside diameter of stack (m),

U = mean wind speed (m/sec),

P_a = ambient air pressure (mbar), not corrected to sea level.

T_s = stack effluent temperature (°K).

T_a = ambient air temperature (°K), and

2.68×10^{-3} is a constant with units mbar^{-1} m^{-1}

Holland[11] suggests that 10 to 20 percent of the rise given by the equation be added for unstable conditions and/or equal amounts subtracted for inversions.

Since the Holland equation is an empirical formulation, it should not be applied to stacks exceeding the ranges on which it was developed, i.e., stack diameters from 1.7 to 4.3 meters and stack temperatures from 82 to 205 °C.[12] It should also be noted that the downwind displacement between the stack and the point at which the maximum rise occurs is not measured by this method. Thus, this technique should not be used if the resulting hazard distance is within a few hundred meters from the stack, since this value will tend to underestimate the true distance.

When more accurate estimates of cloud rise are required, the following methods derived by Briggs are capable of providing such results.

12.2   The Briggs Model.

An important result of the study by Briggs[10,13] was that buoyant plumes were found to follow a 2/3 power law. The assumptions were made that buoyancy is conserved and that any initial momentum is negligible for a very buoyant plume in unstratified surroundings.[13] The form of the equation:

$$\Delta h = 1.6 \ F^{1/3} \ x^{2/3} \ U_s^{-1} \tag{A-51}$$

where

F = initial buoyancy flux divided by $\pi \rho$ (m^4/sec^3).

$$= \left(\frac{T_s - T_a}{T_s} \right) \left(\frac{g \ V_s \ d_s^2}{4} \right)$$

T_a = ambient temperature (°K),

T_s = plume temperature (°K),

V_s = mean stack effluent velocity (m/sec).

g = gravitational constant (9.8 m/sec^2),

d_s = internal stack diameter (m),

x = downwind distance from stack (m), and

U_z = average wind speed at top of stack (m/sec).

The constant, 1.6, in equation A-51 is based on a "best-fit" of empirical data and corresponds to a value of the entrainment coefficient of 0.6, which is typical of large fossil-fuel plants.

The vertical structure of the wind in the lowest turbulent layer, from the surface to approximately 300 m, has been adequately described by the empirical power law in which

$$U_z = U_r(z/z_r)^p \qquad \text{(A-52)}$$

where

U_r = wind speed measured at height z_r (m/sec),

z = stack height (m), and

p = wind profile exponent (nondimensional).

Values for p are provided for various locations in Appendix D of the handbook.[8] Since the values presented there are topographically dependent and not site-dependent, the wind profile exponents can also be used for sites not included. On the basis of terrain type, values associated with Dugway Proving Ground can be used for flat terrain, those for Anniston Army Depot for rolling or hilly terrain, and those for Johnston Island can be used for marine sites.

For neutral stability, a good approximation is given by:

$$\Delta h = 1.6 \; F^{1/3} \; U_z^{-1} \; x^{2/3} \qquad \text{when } x < 3.5 \; x^*$$

$$\Delta h = 1.6 \; F^{1/3} \; U_z^{-1} \; (3.5 \; x^*)^{2/3} \qquad \text{when } x > 3.5 \; x^* \qquad \text{(A-53)}$$

where x^* is calculated by the relationships,

$$x^* = 14 \; F^{5/8} \qquad \text{when } F < 55 \; m^4/sec^3$$

$$x^* = 34 \; F^{2/5} \qquad \text{when } F > 55 \; m^4/sec^3. \qquad \text{(A-54)}$$

For stable regimes, equation A-51 is valid approximately to the maximum distance $x = 2.4 \; U_z \; s^{-1/2}$ where s is defined by:

$$s = \frac{g}{T_a} \frac{\partial \theta}{\partial z} \qquad \text{(A-55)}$$

where $\frac{\partial \theta}{\partial z}$ = average potential temperature gradient (°K/m).

Beyond the distance, x, defined above, the height of the plume centerline levels off under stable conditions at about

$$\Delta h = 2.5 \; (F/U_z s)^{1/3} \qquad \text{(A-56)}$$

In situations where there are calm or very light winds under stable conditions, the following formula developed by Morton, Taylor, and Turner[14] best applies if it gives a lower plume rise than equation A-5C:

$$\Delta h = 5.0 \ F^{1/4} s^{-3/8}.$$ (A-57)

Briggs[13] notes that equations A-53 and A-54 apply satisfactorily in unstable conditions as well, and also in slightly stable conditions, if they give a lower plume rise than equation A-56.

12.3 The Briggs-Thomas Model.

Thomas[15] also working with the "two-thirds power law," determined plume rise to correspond to the following formulation, which uses the Pasquill categories for determining atmosphere stability classification.

$$\Delta h = CF^{1/3} U_s^{-1} \ x^{2/3}$$ (A-58)

Based on observations under various stability conditions:

$$C = 1.065 - 6.25 \ \frac{\partial \theta}{\partial z}$$ (A-59)

where $\frac{\partial \theta}{\partial z}$, the average potential tempeature gradient, is defined in Table A-3.

Table A-3. Average Potential Temperature Gradient

Stability	Pasquill stability category	$\frac{\partial \theta}{\partial z}$
		($^{\circ}$K/m)
Extremely unstable	A	-0.010
Moderately unstable	B	-0.008
Slightly unstable	C	-0.006
Neutral	D	0.000
Slightly stable	E	0.010
Moderately stable	F	0.037

12.4 Jet Plumes.

In the case of jet plumes, where momentum is the overriding factor in plume rise, it is recommended that in neutral, windy conditions the trace of the centerline is given by:

$$\Delta h = 1.44 d_s \ (V_s/U_z)^{2/3} \ (x/d_s)^{1/3} \qquad \text{(A-60)}$$

and is valid at least to the point

$$\Delta h = 3 \cdot V_s/U_z \cdot d_s \text{ providing } V_s/U_z > 4. \qquad \text{(A-61)}$$

For windless conditions, the jet rises to

$$\Delta h = 4(F_m/s)^{1/4} \qquad \text{(A-62)}$$

where

$$F_m = \text{momentum flux parameters}$$

$$= \frac{\rho_O}{\rho_A} \ V_s^2 \cdot \frac{d_s^2}{4}$$

ρ_O = density of gases emitted from stack (gm/m^3)

ρ_A = density of ambient air (gm/m^3).

Other variables as defined above.

From a purely theoretical standpoint, Briggs suggests using the following formula in a stable regime with some wind and also recommends its use if it predicts a lower rise than either equation A-61 or A-62. The theoretical formula based on his model is:

$$\Delta h = 1.5 \ (F_m/U_z)^{1/3} \ s^{-1/6} \qquad \text{(A-63)}$$

12.5 Rise of Heated Clouds.

Technical Paper No. 10[1] presents a methodology for the calculation of the rise of a heated cloud resulting from a fire or explosion in a stable atmosphere. The method is based on the work by Briggs[13] and extended by Dumbauld et al.[16] This presentation of the method has been simplified and the notations made to conform with that used in this handbook.

The maximum cloud rise, Δh, downwind from an instantaneous source in a stable atmosphere, is given by

$$\Delta h = \left[\frac{6F}{\gamma_I^3 \cdot s} + \left(\frac{r}{\gamma_I}\right)^4\right]^{1/4} - \frac{r}{\gamma_I} \qquad (A-64)$$

$$F = \text{buoyancy parameter}$$

$$= \frac{gQ_h}{\pi\rho_\alpha C_p T_a}$$

g = acceleration due to gravity (9.8 m/sec^2),

Q_h = effective heat released (cal),

ρ_α = density of ambient air (gm/m^3),

C_p = specific heat of air at constant presssure (0.24 cal/gm °K),

T_a = ambient air temperature (°K),

γ_I = entrainment coefficient for an instantaneous source (dimensionless),

r = initial cloud radius (m),

$s = \dfrac{g}{T_a}\dfrac{\partial\theta}{\partial z}$ restoring acceleration per unit vertical displacement for adiabatic motion in atmosphere (sec^{-2}),

$\dfrac{\partial\theta}{\partial z}$ = vertical potential temperature gradient (°K/m).

(Estimates for this are provided in Table A-3.)

It is recommended[1] that a value for γ_I of 0.64 be used for large explosive releases.

The maximum cloud rise Δh, downwind from a quasi-continuous source (see section 7.4 of the handbook)[8] in a stable atmosphere is given by:

$$\Delta h = \left[\frac{6\,F_c}{U\gamma_c^2 s} + \left(\frac{r}{\gamma_c}\right)^3\right]^{1/3} - \frac{r}{\gamma_c} \qquad (A-65)$$

where

$$U = \text{mean wind speed (m/sec)},$$

$$F_c = \text{continuous buoyance parameter}$$

$$\frac{gQ_c}{\pi \rho_a C_p T_a}$$

Q_c = effective heat released (cal/sec),

γ_c = entrainment coefficient for a quasi-continuous source dimensionless

Other variables as defined above.

Briggs[13] cites a value of 0.5 for γ_c for buoyant plumes such as those resulting from uncontrolled fires.

13.   CONCENTRATION IN AN INVERSION BREAKUP FUMIGATION

A ground-level inversion may be eliminated by the upward transfer of heat when the ground is being warmed by solar radiation. In the transient situation, substances that have been emitted into the stable layer will be mixed vertically as they are reached by the thermal eddies. As a result, the ground level concentrations can increase over what would be expected under either stable or unstable conditions. This process has been called fumigation.

In the Workbook of Atmospheric Dispersion Estimates, Turner[17] recommends essentially a box model with the height taken as the height of release plus 2 sigma-Z. He further suggests that the cloud width be increased by a 15-degree angle through the downward transport.

$$\chi_F = \frac{Q}{\sqrt{2\pi}\, U \sigma_{yF} H_I} \tag{A-66}$$

χ_F = the peak concentration under fumigation conditions

$\sigma_{yF} = \sigma_y + H/8$

$H_I = H + 2\sigma_z$

σ_y is for stable conditions

Other parameters are as defined previously.

14.   IGLOO FIRE MODEL, M55 ROCKET

The most complete report on the consequences of an igloo fire containing M55 chemical munitions is given in ORG Report 44.[18] The reader is

advised to consult this report for an understanding of the many aspects of this problem. The following is a tabulation of particulars extracted from this report that may be useful in routine downwind hazard calculations.

14.1   GB Fill.

14.1.1   The source is taken as the fill of 2.52 percent of the rockets stored.

14.1.2   The agent is released according to the following schedule:

Time interval (min)	Source (%)	Cumulative time (min)
15	91	15
5	6	20
40	3	60

14.2.1   VX Fill.

14.2.1   The VX source is taken as 0.164 percent of the total fill.

14.2.2   This source is released over a period of 5 minutes.

15.   PALLET MODEL, M55 ROCKET

Data on sympathetic detonation within a pallet of M55 rockets is reported in AEO Report No. 24-77.[19] This report concluded that the equivalent of 2 rockets would detonate, and the contents of the remaining 13 would spill and be distributed over an area 9 x 61 meters. A subsequent analysis by CSL* indicated that this evaporative source could be approximated as a normal volume where SXS = 0.83 m and SYS = 7.0 m.

16.   SELECTION OF ATMOSPHERIC STABILITY

The classification scheme for atmospheric stability employed in subroutine PSST3 is based on a system proposed by Pasquill.[20] The system was quantified and reduced by a system of logical decisions by Turner[21] based on the elevation angle of the sun, cloud cover, and cloud height. These parameters determine a net radiation index for heating of the surface during the day and for cooling at night. The stability class is then estimated as a function of wind speed. This logic is summarized in Tables A-4 and A-5.

17.   DIFFUSION PARAMETERS IN FOREST TERRAIN

The diffusion parameters recovered from subroutine WOODS are a matter of professional judgment based on a body of field data. These estimates first

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*Analysis done by C. G. Whitacre, CRDEC, in 1978 in which rocket fragments were traced to infer the distribution of liquid agent. Unpublished data.

appeared in a GCA Corporation progress report for January 1967. The author, Dr. Harrison E. Cramer, revised these estimates in April of that year at the request of ORG. The values were recorded in a Memorandum for Record, 5 May 1967, by Mr. Irving Solomon of ORG.* See Table A-6.

Table A-4. Net Radiation Index

Cloud cover (1/10)	0-5	6-9			10		10		9-5	4-0
Cloud height (1000 ft)		> 16	16-7	< 7	≥ 7	< 7	< 7	≥ 7		
Solar altitude										
< 15°	1	1	1	1	1	0	0	-1	-1	-2
15-35°	2	2	1	1	1	0				
35-60°	3	3	2	1	2	0				
> 60°	4	4	3	2	3	0				

Header spanning: Day columns (0-5 through < 7), Night* columns (< 7, ≥ 7, 9-5, 4-0).

*Night is defined as the period from 1 hour before sunset to 1 hour after sunrise.

Table A-5. Pasquill Stability Category as a Function of Net Radiation Index and Wind speed

Wind speed m/sec	Net radiation index						
	4	3	2	1	0	-1	-2
< 1	A	A	B	C	D	F	F
1	A	B	B	C	D	F	F
2	A	B	C	D	D	E	F
3	B	B	C	D	D	E	F
4	B	C	C	D	D	D	E
5	C	C	D	D	D	D	E
6	C	C	D	D	D	D	D
> 6	C	D	D	D	D	D	D

*A copy of this memorandum is on file in the Studies and Analysis Office, CRDEC.

Table A-6. Diffusion Parameters in Forest Terrain

Windspeed			α	S_{y100}	β	S_{z100}
Reference outside canopy		Transport under canopy				
mph	m/sec	m/sec				
Deciduous Forest, Winter						
1	0.45	0.089	0.8	12.8	1.2	8.97
5	2.20	0.45	1.0	12.1	1.2	9.66
12	5.40	1.1	1.0	12.0	1.2	10.35
20	8.90	1.8	1.0	12.0	1.2	10.35
Mixed Deciduous and Coniferous Forest, Winter						
1		0.089	0.8	18.2	1.3	12.96
5		0.36	1.0	17.5	1.3	13.78
12		0.8	1.0	16.8	1.3	13.78
20		1.3	1.0	14.5	1.3	13.78
Coniferous Forest						
1		0.089	0.8	23.5	1.3	14.59
5		0.36	1.0	22.5	1.3	15.4
12		0.8	1.0	19.0	1.3	15.4
20		1.3	1.0	14.0	1.3	15.4
Mixed Deciduous and Coniferous Forest, Summer, and Deciduous Forest, Summer						
1		0.045	0.8	29.0	1.4	20.4
5		0.22	1.0	26.5	1.4	20.4
12		0.54	1.0	22.5	1.4	20.4
20		0.89	1.0	16.5	1.4	20.4
Tropical Rain Forest						
1		0.045	1.0	53.0	1.0	34.5
5		0.13	1.0	36.0	1.0	34.5
12		0.27	1.0	26.0	1.0	34.5
20		0.45	1.0	23.0	1.0	34.5

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APPENDIX B

NOTES ON PROGRAM CONSTRUCTION

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APPENDIX B

NOTES ON PROGRAM CONSTRUCTION

1. INTRODUCTION

The following is a collection of notes on the internal workings of
the D2PC program. These are like external comment cards (on paragraphs). The
normal user of the program will not need to remember all of this, but it should
be useful for any future modifications.

The program is written in FORTRAN 77 and was originally compiled and
tested on the UNIVAC 1100/60 computer. The source program was then transferred
to an IBM compatible Eagle PC and recompiled with microsoft FORTRAN 3.3. The
only changes made in the source code were the format of the INCLUDE statement
in MASTER (see Section B-5 below) and the addition of a back slash (\) to line
27 of subroutine DEF. This permits keyboard entries to be displayed on the
same line with the word INPUT.

2. COMMON

Communication between MASTER and the subroutines is, for the most
part, accomplished through a block of unlabeled common (107 words). With the
expansion of the ALL statement to include all input variables, common was
extended to all of the subroutines except ERF, WOODS, UNT, and READA. The
other subroutines that have arguments in their CALL statements (EVAP, PLRS,
STAB, and DEF) employ the common block but identify only a segment of the
variable names in each. Of course, the segment in each subroutine must coincide
with the position in MASTER. This is accomplished by introducing dummy arrays
before and after the segment to position the variable of interest. The remaining
values are exchanged through the argument list. The MASTER and subroutines DDS,
CDS, and QLIST contain the complete common list.

3. THE ALL QUESTION

Beyond the exchange of information, the common block of data is also
used by MASTER to assign values to the variables during the random order input
from the ALL question. This is accomplished through a parallel array, PNU,
which lists the three-letter literal name of each variable as it is known in
the ALL question. The PNU array corresponds to the COMMON block beginning with
variable PR(1) and ending with ID2.

This random order input is accomplished by first searching the PNU
table to identify the position of the variable name and then storing the argument
in the corresponding position in COMMON. The variables PR(1), LOCT(1), and
IPR(1) are taken as the reference positions.

There are several complications in this storage process. The variable
name is always alphabetic, but the argument can be real, integer, or alphanumeric.
The real and integer can be entered through the free format available in FORTRAN,
but an alphabetic input in the data field is more troublesome. This is accom-
plished in FORTRAN 77 by reading the field, initially, as a character string and

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then rereading this string with different formats. This created another problem in that the rereading statement (where the string variable name is given as the input channel) would not accept the free format designation. The free format is approximated by using the BN (blank null) option in the format; this permits free positioning within the field specified, but each variable must be in a new field as specified. Thus, the free format is limited to one variable per input. This is acceptable for the ALL question since the first field is always three alphanumeric characters, and only the second field needs to be in free format.

Table B-1. Storage Process

	Variable					Variable		
	Literal	Program	J			Literal	Program	J
1.	TIM	RP(1)	1		35.	CRD	CR	1
2.	DLX	DXT			36.	SLA	SLA	1
3.	HTS	HT			37.	SLO	SLO	1
4.	HML	HML			38.	CCT	CC	1
5.	SXS	SXS			39.	CHT	CH	1
6.	SYS	SYS			40.	SUN	AE	1
7.	SZS	SZS			41.	PMM	PMM	1
8.	TMC	TIVCH			42.	ZZO	ZO	
9.	WND	UT	1		43.	LOC	LOCT(1)	1
10.	BRT	BR			44.	SEA	SEAT	1
11.	SKF	SF			45.	MUN	MUNT	1
12.	TMP	TMP	1		46.	AGN	AGNT	1
13.	ALF	ALFA			47.	REL	REL	1
14.	SYR	SY100			48.	STB	MTC	1
15.	BTA	BETA			49.	SUR	SUR	1
16.	SZR	SZ100			50.	WOO	WT	1
17.	SMH	Z			51.	HLD		
18.	REF	RC			52.	RLS		
19.	SEV	V			53.			
20.	QQQ	QS	1		54.	IRT	IPR(1)	
21.	TEV	TEVP	1		55.	NDI	ND	
22.	ARE	SAVP	1		56.	OPO	IPO	
23.	LEN	FL	1		57.	2MC	I2MC	
24.	FMW	FMW	1		58.	IMA	IMA	
25.	FMV	FMV	1		59.	OPC	IPC	
26.	VAP	VP	1		60.	IMM	IMM	1
27.	BPT	BP	1		61.	IDD	IDD	1
28.	HST	HS			62.	HRS	IHR	1
29.	DST	DS			63.	NOV	NOV	
30.	TST	TSC			64.	INP	INP	1
31.	VST	VS			65.	MNR	MRL	
32.	RDE	RDE			66.	NMU	NMU	1
33.	FRO	P			67	NCI	ND	
34.	HRL	HR						

For convenience, this storage process divides the PNU table into three segments. Elements 1 through 42 are input as real variables; 43 through 53 are alpha, and 54 through 67 are integer. The integer portion uses variable IPR(1) as a new reference point. Table B-1 lists the variable names as identified by PNU, the name of the variable as it appears in COMMON, and the corresponding flags in the J table. (The J table is discussed later under rescan).

The control variables (ALL, STP, RST, RSN, GTO, etc.) do not require storage of an argument, and these are intercepted by a scan against PNUC before the scan of the PNU table.

The commands hold (HLD) and release (RLS) are identified from the PNU table to determine the value of the index I. An additional scan of the PNU table is then performed with the argument (PRT) to establish which variables are to be flagged for hold. This generates the index II, which stores or clears a flag in the K array.

The operation of the program rescan in successive runs was discussed in the body of the report. The mechanism that controls this rescan is based on the sum of J(I), which is accumulated with each entry in the ALL question. When the word ALL is given, this sum is tested and if greater than zero the rescan will occur.

4.   INDEX NAMES

All of the multiple choice answers that are read in questions 2, 3, 4, 6, 8, and 9 are converted to integer index values for use in the program logic. Table B-2 identifies the variable name with the index name for each.

Table B-2. Variable and Index Names

Variable	Index
LOC	IL
SEA	IS
MUN	IMU
AGN	IA
REL	IR
STB	IM

5.   THE INCLUDE STATEMENT

The MASTER program contains an INCLUDE (line 22). The operation of this statement will be explained to help the user develop an alternative if his system does not permit the INCLUDE statement.

In the UNIVAC version of this program the statement appears as INCLUDE HMLMDR. Here HMLMDR is a FORTRAN PROC that is listed at the end of the program (Appendix E). In operation, the PROC is included at compile time as if the statements were written into the program.

In the 1100/60 system, the PROC must be prepared by processing with a PDP,F processor and available in the file whenever the calling program is compiled. For the MICROSOFT processor, the format of the INCLUDE statement is changed to $INCLUDE: 'HMLMDR.FOR' with the dollar sign in column 1.

6.   INTERNAL INDICATORS

Internal indicators are variables that are assigned values within a program to convey information to another part in the program or to remember for a later time. A few of these will be discussed here for the user's (programmer's) information.

The indicator IDEP is used by MASTER to select the downwind model in subroutine DDS. A value of -1 indicates that the instantaneous release of HD is requested. This will cause DDS to CALL HD42, which will compute the airborne source and assign special diffusion parameters.

IDEP is assigned a value of 1 when the inhalation-deposition model based on the M55 rocket is used. Here the vapor source is taken as 13 percent of the fill weight, and the downwind dosage at each distance is converted to the intraveneous dose, which is then added to the percutaneous dose from the impaction model. IDEP is assigned a value of 2 for the M23 land mine. The downwind hazard calculation for the M23 is based on the percutaneous dose alone. Both the M55 and M23 models are part of DDS.

The indicator I2MC is the internal equivalent of 2MC in the ALL statement and is used to control the 2-minute correction in DDS. Normally the 2-minute correction is applied to GB and VX vapor at levels of response above "no effects." In program D2 the D(1) level of response will not contain the 2-minute correction unless specifically instructed. In normal operation, when the response dosages are drawn from the tables automatically, the "no effects" value is written into D(1). Then, if the value of MNR is set to zero, the DDS subroutine will change I2MC to zero after the distance for D(2) has been computed, and thus drop the 2-minute correction for D(1).

In the event that one does not wish I2MC to change for D(1), a hold can be placed on I2MC (HLD 2MC) in the ALL question. The hold flag is stored in the K table, but the K table is not available to subroutine DDC. Therefore, the hold signal is transmitted to DDC by setting the value of I2MC at 1 instead of 2, which is the usual 2-minute correction signal.

The K table is used by MASTER to remember the variables that have been flagged as hold. This is a 67-element table that corresponds to PNU. A flag can be set for any variable (in ALL), but only the few that can be overwritten by rescan have inhibit tests installed.

Element 67 in the K table corresponds to NCI in the PNU list. This element is used to place an automatic hold on NCI when IMA is set to 1, 2, or 3. The value of K(67) is given the value of PRT at the time IMA is identified in the ALL statement. Then, since IMA = 0 in the dosage configuration, this releases the hold on NCI automatically. The D table in COMMON is used to store both the values of DI and CI, and NDI and NCI are defined within the program as ND. Thus, a hold placed on either NDI or NCI will prevent the table look-up of DI.

When the plume rise subroutine, PLRS, is called by specifying releases STK, STJ, FLS, or FIR, a special programming problem is created by permitting the cloud to rise with downwind distance (OPC = 2 or 3). When these release modes are specified, the MASTER calls PLRS with the argument XI set to zero. This begins a process in PLRS that can list the DHT = $f(x)$ table (OPC = 1 or 3) or the various values of DHTMX, which is the maximum cloud rise. In this process, the distance for maximum rise (XMX) is stored, and the stack height (HST) is added to DHTMX and stored in COMMON as HT. This is the value used by DDS or CDS if OPC is given as 0 or 1. If OPC is given as 2 or 3, this maximum height is listed as the release height in the second line of output from DDS or CDS, but HT is now recalculated for each downwind distance and listed in the output.

To control the interchange between PLRS and DDS or CDS, a control indicator, IRTP, is initially assigned a value of IRTP = 1 (or IRTP = 0 when 4 < IR < 9) in DDC or CDC. This first controls the bypass of CALL PLRS. If PLRS is called, IRTP is redefined in PLRS as -1 when OPC = 2 or 3. Then as x increases beyond XMX, the value of IRTP is changed to one. This now bypasses the call to PLRS. IRTP is also used in the logic of selecting the contour length (or hazard distance) to a specified dosage. Here the calculation of downwind distance continues one cycle beyond the height where the maximum height of the cloud has been reached. This prevents the program from selecting the hazard distance from the first mode of the bimodal distribution, which can be caused by the rising cloud.

The indicator IER is used in the interpretation of question 15 to remember that there was an error on the initial reading of PRT. After PNUT is identified, IER causes PRT to be reread as an alpha field.

The variable IRL is set to one to remember that the dosages of interest have been drawn from the tables and thus that the interpolated distances can be labeled on output (1%, ND, NE). Values that are input with NDI are not labeled.

The indicator ISM is set to one when the command SMD is used to initiate execution of DDS. When ISM equals one, the table of dosages (DS(K)) is not cleared from the previous run. The dosages for corresponding values of X are always added to the current value so that this will sum the dosages from the previous run (or runs) with the present and thus accumulate the dosages for multiple releases.

The arguments interchanged with subroutine DEF are normally the question number, IQ, and the return indicator, IRT, that tells the calling subroutine when the question has been asked (0 = N, 1 = Y). (Note that this internal IRT is different from the IRT in the control commands.) Many variations are used. A zero value for IQ causes the IQT table (which remembers which questions have been asked) to be cleared to zero; a negative question number clears the block on that question only. An IQ value greater than 40 will print the options and definitions for the question defined by the number minus 40. An IQ value of 39 prints the information table when NOV equals 3.

When IQ equals 40, a negative value of IRT will print one of the four tables requested with the TAB command. A positive value of IRT will list the options and definitions requested for the question requested by a DSP command. An IQ value of 40 and an IRT of zero prints the table definition requested by

three question marks. These controls are set up in the MASTER in response to commands TAB, ???, and DSP.

When TMC (time to met change) is assigned a value in the ALL question, the program converts this time into the distance (XCH) the cloud would travel at the specified wind speed. If the distance to minimum response exceeds XCH, the program will stop with the questions:

> INPUT: STB
> INPUT: WND, HML, TMC.

This is a request for the new met conditions. The new value of TMC is now the length of the next interval in minutes. Internally, the interplay between MASTER and DDS is controlled by TIVCH, which transmits the value of TMC to DDS, and the indicator, IMTCH, which controls the special return to MASTER.

7.   ADDITIONAL CAPABILITIES

There is a data base for stability categories I and N. These are recognized by MASTER, and values for the diffusion parameters are given in DDS and CDS. These parameters are intended for inversion and neutral stability in urban areas. These values were taken from a 1957 Fort Detrick Report* and further study is planned.

An additional capability is a provision to compute the cloud width with distance (OPO = 3). The user is cautioned in following these estimates of width in safety applications. The width is measured from the pattern centroid, but the centroid is subject to shifts with wind direction, terrain, and obstructions. Thus the width is useful for area calculations, but a safety corridor should be wider.

The commands RUN and PEEK are intended for deep debugging. The RUN command will cause the program to execute the downwind hazard estimate without considering if the program should first rescan. The PEEK command will cause the program to display the current values in COMMON. The PEEK options are as follows.

> PEEK 1 List QT(), TWL()
>   2 List DI(), DIL()
>   3 List 42 real values
>   4 List 11 alphanumeric codes
>   5 List 21 integer values
>   6 List D-A generated by vapor depletion run

Options 3, 4, and 5 will display the three-character code for each variable (TAB 4) with the current numeric value.

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*CML 2564. Semi-Annual Report, April-September 1954, Contract #DA-18-064-CML-2564, Department of Chemistry, Stanford University. UNCLASSIFIED Report.

8.　　　SUBROUTINE UNT

　　　The units conversion capability provided by subroutine UNT is designed to be invisible to the user when conventional metric units (as specified in the questions) are used. That is, the user needs to input no special code to identify these units. Other units, however, must be identified so that the program can initiate the conversion.

　　　The conversion process is initiated when a read error is created in one of the questions requesting numeric input. This error occurs when alpha characters are found in the free format portion normally used to input numeric information. At this point, the program rereads the last input, now extracting the first two characters as the conversion code. If this is successful, the code is searched with the literal codes in table MNE to identify the proper conversion factor from table UC. Then, if the units are recognized as a volume, the density from table DN25 is included. If the code is not understood or the reread contains an error, the program clears the input block, lists the unit codes, and loops back to repeat the question.

9.　　　SUBROUTINE READA

　　　Subroutine READA is provided to extract the units conversion code from numeric inputs and call UNT. The arguments are defined as follows:

> UM is the unit code
> IA is the agent index
> PRT is the argument being converted
> IQ is the question number
> IRT is the return message to repeat.

　　　The argument is processed as PRT but returned to the calling program as the fourth argument in the call statement.

10.　　　SUBROUTINE QLIST

　　　The text of the numbered questions now come from subroutine QLIST. In operation the program calls DEF with the question number. DEF determines if the question has been asked and if not prints options and definitions as directed by the value of NOV. It then calls QLIST, transmitting the value of IRT. If the question has not been asked, the question and code are printed. On rescan when the question has been asked, QLIST also recovers the current value of the parameters from COMMON and displays this with the question.

　　　The text of the questions is stored as array QTAB and the three-character parameter codes are listed in a parallel array, SYM. When IRT = 1, the text of the question and the parameter code indicated by IQ are displayed. When IRT = 1, the question and code are followed by the current value of the parameter. This is accomplished through array IQR, which identifies the location of each parameter in COMMON in terms of the question number. Another array, IQM, specifies how many values are associated with each question.

　　　The use of arrays PR(1), LOCT(1), and IPR(1) as markers in the common table is recognized as something of a tour de force in this program.

Equivalence arrays would have been easier to follow (or explain). It should also be noted that placing the character strings in COMMON is not standard for the UNIVAC FORTRAN 77 and it will complain, but it still works.

11.   SUMMING D(X)

A two-column table, DS (dimensioned 51,2) is defined in subroutine DDS to sum dosages at corresponding distances from multiple releases. The current (last generated) dosages are written in level 1 with each execution. Level 1 may be summed into level 2 with the command SMD. If the command SMP is given before the last ALL, the next downwind distance is distance based on the last Sum (level 2) and the current DP (level 1). The Sum column is cleared with the command SMC.

These operations are performed in subroutine DDS and are controlled from MASTER by indicator ISM. ISM is set to zero for SMC, to 1 for SMD, and 2 for SMP. Otherwise, ISM equals 3.

These control commands are intercepted in the PNUC loop in HDS3 (line 250). The commands SMC and SMD set the value of ISM in HDS3 and then call DDS. In DDS the value of ISM causes DS(I,2) to be cleared or summed from DS(I,1). Control then returns to the ALL loop in HDS3. The command SMP sets ISM to 2, which will cause DS(I,2) to be added to DP at each X in the next execution of DDS. ISM is set to 3 each time the ALL loop is entered.

12.   VAPOR DEPLETION

The vapor depletion model that is described in Appendix C is implemented in the program by subroutine VDPL. This subroutine is divided into four parts which are (in effect) entered separately. The first computes the deposition velocity, DEVP, as a function of wind speed, stability, and roughness length.

The second entry estimates the peak dosage (or concentration) and establishes the table of dosages over which the area will be integrated. The lower limit for this distribution is taken as one-tenth of the minimum dosage of interest specific in the main program. This dosage-area table can be output at the end of the program with a PEEK 6 command from the ALL question. The output option, OPO 4, will cause the contour half-widths for this distribution to be listed and then the dosage-area table.

The third entry is called for each downwind distance, and the area coverage is accumulated as a function of X. With each call a new estimate of the function of the source still airborne (SDEPL) is made and the adjusted peak value is returned. Two peak values (DP and DPA) are transmitted to the subroutine to accommodate the 2-minute correction for GB and VX. (The area distribution is based on the noncorrected value.) The other parameter values (DX, DXA, XS, and XCH) are provided to adjust the area integration when a stability change is called from the master program.

The fourth entry point lists the dosage-area distribution. This is printed by a PEEK 6 or at the end of a run with OPO 4.

The UNIVAC version of this program uses the different entry points. The PC version enters at the top and then branches to the section as directed by the indication INT. The function of the source remaining airborne (SDEPL) is printed for each distance when OPO is greater than zero and before each estimated distance when OPO equals zero.

The area is accumulated by summing the rectangular strings defined by delta-X, or DX, and the contour half-width. This is rather crude and can be improved by decreasing DX from the default value of 10. This can be changed by assigning a new value to DLX in the ALL question; this value will be augmented by the program according to the following rules:

$$\text{If } (X \geq DX*10.) \quad DX = DX*10.$$

with
$$X_{i+1} = X_i + DX$$

except
$$X_1 = 1$$

and
$$X_2 = DX$$

Thus, DLX should be selected with the progression it will produce in mind. A value of two is a reasonable alternative.

13.   DATA TABLES IN D2PC

The following list identifies the data tables for each subroutine in program D2PC. These variables are selected with the expectations that some users may wish to add to the present data sets or substitute others in these tables. The dimensions of each table are listed, and each component is specified for cross reference. The parameters marked with an asterisk would require logic changes in the program if these are altered. Those marked with two asterisks would require logic changes if certain items (numeric position) were changed.

HDS3

  HMLT (6, 4, 11)   Height of the mixing layer (m)
    6   Stability categories A + F
    4   Seasons winter to fall
   11   Sites specified

  QF (10, 3)   Item fill weights (mg)
   10   Items
    3   Fills

  SYSM (10)   Lateral source sigma for each item (m)

  SZSM (10)   Vertical source sigma for each item (m)

  PMMT (12)   Average atmospheric pressure at each site (mm Hg)

  DI (3, 17)   Dosage response levels (mg-min/m^3)
    3   Levels (ascending dosage)
   17   Substances

FMWT (17)   Molecular weight of substances

*RELT (10)   Methods of release

**AGN (17)   Substance codes (2 characters) (first three have complex logic control)

*PNUC (16)   Control codes (3 characters)

*PNU (77)   Parameter codes (3 characters)

*J (67)   Rescan indicator for parameters

MUN (10)   Item codes

*IST (11)   Stability codes (1 character)

LOC (12)   Site codes (3 characters)

SEA (4)   Season codes (3 characters)

<u>EVAP</u>

AGN (15)   Substance codes (2 characters)

FMW (16)   Molecular weight ⎫

FMV (16)   Molecular volume ⎬ 16th space for read-in

PP (16)   Boiling (°K) ⎭

A (15) ⎫

B (15) ⎬ Constants for vapor pressure of substances

C (15) ⎭

FP (15)   Freezing point (°K)

<u>DDS</u>
<u>CDS</u>

ALFAT (6)   Alfa for Pasquill Category (A → F)

BETAT (6)   Beta for Pasquill Category (A → F)

SY100I (6) Reference sigma Y at 100 m for instantaneous release (m)

SY100T (6) Reference sigma Y at 100 m for continuous release (m)

SZ100T (6) Reference sigma Z at 100 m (m)

*Revision will require program logic changes.
**Certain items (in numeric order) will require logic changes.

*SY100C (2, 3)   Reference sigma Y at 100 m in urban areas (m)
  2   Stability (neutral and stable)
  3   Wind speed classes

*SZ20C (2, 3)   Reference sigma Z at 20 m in urban areas (m)
  2   Stability (neutral and stable)
  3   Wind speed classes

*BETAC (2, 3)   Beta for urban areas
  2   Stability (neutral and stable)
  3   Wind speed classes

*ST (11)   Stability codes (A-F, N, I, U, S, W)

  RL (3)   Response level labels

UNT

  UMT (25)   Input unit code (2 characters)

**UC (25)   Conversion constant (4th is °F → °C)

  DN25 (18)   Density of substances at 25 °C (18th is space for read-in)

  MNE (34)   Standard names of units

  IK (25)   Selects output for units input

QLIST

  IQR (36)   Locates variable in common list by questions

  IQM (36)   Specifies number of variables by question

  QTAB (37)   Question list (30 characters) (37th extension of question 29)

  SYM (37)   Symbol for variable by question

VDPL

  PT (6, 3)   PT from model by stability and surface
    6   By stability (A → F)
    3   By surface type (flat, rolling, sea)

  ITT (12)   Surface type by site

  FKMS (6)   kms from model by stability (A → F)

  ZOT (12)   Roughness length by site (cm)

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*See footnote on page 70.

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APPENDIX C
VAPOR DEPLETION

by

Dale W. Sloup

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APPENDIX C

VAPOR DEPLETION

1. INTRODUCTION

After agent is released from chemical munitions, fine aerosols and gases transport with the wind and are eventually removed from the atmosphere by deposition upon many types of surfaces (water, soil, vegetation, etc.) with possibly some chemical changes occurring with time. Atmospheric turbulence, Brownian motion, impaction, and sorption are some of the processes causing agent to be dropped from the cloud and retained on surfaces.

The most common mathematical techniques for consideration of the agent fall-out mechanisms and surface deposition are called the "source depletion" and "partial reflection" models.[1] These models apply to very fine aerosols and vapors of approximately 10 μm or less, in diameter. The partial reflection approach seems to perform well near the source and is fairly easy to use. However, the "source depletion" technique has been shown to perform better for far downwind distances. For this reason, the source depletion course was followed for use in our general chemical hazard prediction model.

Chamberlain[2] and other investigators have presented the mathematical derivation of a depletion factor as a function of downwind distance for various continuously emitting plume type sources. However, as far as can be determined, source depletion models that characterize "instantaneous" type source releases, such as would be expected for chemical projectiles and rockets, have never been reported in the open literature. Therefore, an attempt was made to adapt the "continuous source" approach to an instantaneous release. However, this did not work out because the numerical integration became quite messy and was not followed through.

2. EMPIRICAL DEPLETION MODEL

Still faced with a need for an instantaneous depletion technique, an alternate empirical approach was proposed. This proposed technique and dosage requires calculation of an effective deposition velocity (v_d) and dosage and/or concentration area coverage as a function of downwind distance. The v_d values is easy enough to calculate, and the current D2 program is readily adaptable to computing dosage/concentration contours. Hence, this simple empirical approach was chosen for incorporation into the Chemical Hazard Prediction Methodology and is presented below.

For a surface that has perfect retention[3] of the material reaching it, the v_d value can be determined in terms of the wind-speed profile, friction velocity, and surface roughness length parameter as follows:

Using the wind speed profile investigated by R. Frost[4] and represented by a power law function across stability conditions as follows:

$$u(z) = u(2) \cdot \left(\frac{z}{2}\right)^{\lambda}$$

where

u(2) is the 2-meter wind speed

λ is the Frost power parameter

and

Using the following relationship, compute the friction velocity parameter[5] (u*)

$$u_* = \lambda \cdot K_m^* \cdot u(2) \left(\frac{z}{2}\right)^{\lambda}$$

where

K_m^* is a generalized stability parameter with the following values

Stability	A	B	C	D	E	F
K_m^*	0.9	0.8	0.6	0.4	0.2	0.05

For near surface estimates, z is set equal to 0.01 meters since $u^* \neq 0$ at $z = 0$.

Now

Compute the surface deposition velocity[5] (ν_d) using the following formula

$$\nu_d = \frac{u_*^2}{u(z)} \left(1 + \frac{u_*}{u(z)} \cdot B^{-1}\right)^{-1}$$

again

using z = 0.01 for near surface estimates.

This equation is correct only for vapor adsorption material. The B^{-1} parameter (the dimensionless reciprocal Stanton number) can be computed as follows:

$$B^{-1} = 0.06 \left(196 \cdot u_* \cdot z_o\right)^{0.45}$$

where

u* is computed as stated above and zo is the conventional surface roughness length.

The B^{-1} equation above was deduced from the following formula[6]

$$k \, B^{-1} \sim 0.2 \left(30 R_{e_*}\right)^{0.45} \cdot \sigma^{0.8}$$

with the following assumptions,

k (Von Karman's constant) equals 0.4, the

Schmidt number σ equals 0.076.

Using

$$\text{Reynolds number } R_{e_*} = \frac{u_* z_o}{\nu}$$

where

ν is the kinematic viscosity of air and using a value of 0.153 cm^2/sec, then the following equation is obtained

$$.4 \ B^{-1} = 0.2 \left(30 \left(\frac{u_* z_o}{.153} \right) \right)^{0.45} \cdot 0.076^{0.8}$$

This reduces to the equation,

$$B^{-1} = 0.06 \ (196 \ u_* z_o)^{0.45} \qquad \text{as stated above.}$$

Now that the technique for calculating the ν_d parameter has been presented, formulation of the source depletion factor can be expressed as follows:

The factor for the diminishing amount of material remaining airborne is defined as:

$$\frac{Q(x)}{Q(o)}$$

where

Q(o) is the initial amount of agent released in mg for dosage. Then the amount of material deposited within a dosage contour class can be estimated by using the following functional relationship,

$$QD(x) = \sum_{I=1}^{ND} \left[\left(\frac{D(I) + D(I+1)}{2} \right) \cdot \left(AR(I) - AR(I+1) \right) \cdot \nu_d \right]$$

where

D(I)'s are the dosage contour levels in ascending order, and AR(I)'s are the corresponding accumulative areas as a function of downwind distance-x for these dosage contours.
ν_d is the vapor deposition velocity as calculated above in meters per minute.

then

The resulting source strength factor as a function of downwind distance x can be calculated for use in the Gaussian equations as follows:

$$\frac{Q(x)}{Q(o)} = \frac{Q(o) - QD(x)}{Q(o)}$$

then, from the above equation, the axial peak dosage can be adjusted for vapor depletion for the next x-distance as follows:

$$DP(x+1) = DP(x+1) \cdot \left(\frac{Q(x)}{Q(o)}\right)$$

The above equations were presented using dosage terms. When the user asks for concentration estimates from the program, then the program logic has the following changes.

Q(o) becomes a rate of release; the D(I)'s are in terms of concentration, mg/min; and the AR(I)'s are the corresponding areas for those concentration contours. Then, the axial peak concentration is adjusted as a function of downwind distance -x as

$$CP(x+1) = CP(x+1) \cdot \left(\frac{Q(x)}{Q(o)}\right)$$

The rest of the model constants and relationships used in calculation of the v_d parameter remain the same as for dosage.

The estimate of the fraction of material remaining airborne $\frac{Q(x)}{Q(o)}$

as a function of distance is based upon the amount of area accumulated across dosage contour classes. Hence, this method is sensitive to the number of contour levels chosen (ND) and the incrementation step of the x-distance in representing cloud coverage. These parameter values are internally controlled by the D2PC program and are designed to provide reasonable results.

We feel this approach to be a reasonable alternative for lack of a more vigorous mathematical form. The advantage is that it is not limited in use. It applies equally well to dosage or concentration predictions for partial or total dosage times and across all source release heights and types (point, volume, continuous emitting).

3.   MODEL VALIDATION

No attempt has been made to verify this theory with actual field experimentation. However, the program has been run to compare its predicted depletion factors against estimates reported in the literature[7] and to demonstrate the expected change as a function of stability with downwind distance.

Table C-1 provides the vertical and horizontal reference distance standard deviations and expansion exponents representing three investigators. The Hansen and D2PCA diffusion parameters are taken directly from the referenced reports; however, what are identified as Pasquill parameters are rather coarse straight-line estimates through the curves provided in reference 7. Table C-2 shows the comparison of the three diffusion sets (Pasquill, Hansen, D2PCA) to the "SLADE" depletion values extracted from continuous source depletion curves on page 205 of reference 7. For the Hansen results, a surface roughness value of $z_0 = 10$ cm set was used. To be compatible with the other two, a $z_0 = 1$ cm set of values for σ_{z100} and B should have been used. Then the results for Hansen would have followed the D2PCA predictions much closer than the Pasquill values in Table C-2.

4.   CONCLUSIONS

Some conclusions that can be drawn from Table C-2 are:

- Using this empirical depletion technique, the D2PCA diffusion parameters continue to keep the amount of airborne vapor up closer to the "SLADE" estimates for stability categories A, B, and C. However, for stability categories D, E, and F, D2PCA, Hansen and Pasquill continue to hold the amount of airborne vapor up when "SLADE" shows it should be falling off significantly.

- Overall, for the first one-thousand meters all three sets of diffusion parameter do equally well in comparing with the "SLADE" estimates.

- For hazard analysis studies, it appears that this technique can be used to improve the predictions and provide safe conservative estimates across stability categories and potential diffusion values.

Table C-1. Diffusion Parameters Values Used to Compute the Results of Table C-2

Stability category	Investigator	σ_{y100}	α	σ_{z100}	β
A	Pasquill*	25.2	0.90	18.0	1.63
	Hansen**	25.2	0.90	17.6	0.90
	D2PCA†	27.0	1.0	14.0	1.4
B	Pasquill	20.2	0.90	11.3	1.191
	Hansen	20.2	0.90	11.3	0.85
	D2PCA	19.0	1.0	11.0	1.0
C	Pasquill	13.9	0.90	8.9	0.852
	Hansen	13.9	0.90	8.9	0.81
	D2PCA	12.5	1.0	7.5	0.90
D	Pasquill	9.02	0.90	6.5	0.682
	Hansen	9.02	0.90	6.5	0.76
	D2PCA	8.0	0.90	4.5	0.85
E	Pasquill	6.43	0.90	4.0	0.664
	Hansen	6.43	0.90	4.0	0.73
	D2PCA	6.1	0.80	3.5	0.80
F	Pasquill	4.80	0.90	2.6	0.633
	Hansen	4.80	0.90	2.6	0.67
	D2PCA	4.0	0.7	2.5	0.75

*These estimates are straight-line estimates through the curves.[7]
**Translated to reference distance of 100 meters.[8]
†Taken from the earlier D2PC report.

Table C-2.   Source Depletion Fraction $Q(x)/Q(o)$ for a Wind Speed U_2 of
1 m/sec and ν_d of 0.01 m/sec CONC, Values for a Continuous
Source (Surface Release)

Stability category	Investigator/ Diffusion category	Distance from source (meters) 10^1	10^2	10^3	10^4	10^5
A	Slade*	.95	.80	.75	.71	.70
	Pasquill**	.93	.74	.68	.46	.14
	Hansen[†]	.94	.81	.66	.46	.14
	D2PCA[††]	.93	.72	.65	.60	.50
B	Slade	.92	.75	.62	.60	.59
	Pasquill	.93	.71	.58	.41	.13
	Hansen	.93	.73	.56	.38	.15
	D2PCA	.93	.72	.56	.48	.41
C	Slade	.92	.70	.55	.39	.28
	Pasquill	.93	.71	.53	.36	.12
	Hansen	.93	.71	.53	.36	.12
	D2PCA	.93	.69	.52	.36	.28
D	Slade	.90	.62	.41	.17	.039
	Pasquill	.93	.69	.44	.24	.13
	Hansen	.93	.68	.45	.28	.12
	D2PCA	.93	.61	.38	.26	.12
E	Slade	.90	.55	.30	.071	.006
	Pasquill	.93	.59	.33	.16	.09
	Hansen	.93	.59	.35	.19	.11
	D2PCA	.93	.58	.32	.18	.08
F	Slade	.90	.50	.15	.015	.0005
	Pasquill	.92	.53	.22	.10	.06
	Hansen	.92	.53	.23	.11	.06
	D2PCA	.92	.54	.25	.12	.06

*Reference 7, curves on p 205
**Reference 7, diffusion curves on pp 408-409
[†]Reference 8, p 7
[††]Dispersion parameters as used in CRDC Chemical Hazard Prediction
Program-D2PCA.

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APPENDIX D

GLOSSARY

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APPENDIX D

GLOSSARY

Atmospheric stability (low level)

This is a relative classification of the mixing of the air near the surface. This mixing has been measured as a standard deviation of wind direction changes (σ_A, σ_E) or, in a more indirect way, as the difference in air temperature at two reference heights. (Temperature gradient between 1/2 and 4 meters.) An even more generalized concept is used in this report based on the Pasquill stability categories. In this system, the heating or cooling of the surface is used to establish a net radiation index. These are then tabulated against windspeed to form a table of comparable mixing categories. For the Pasquill system these are identified as A through F, going from very unstable to stable with category D taken as neutral.

Breathing rate (liters/minute)

As used in these models, the breathing rate is the average volume of air aspirated per minute. The rate is usually stated in liters per minute, but must be converted to m^3/min when multiplied by dosage to provide consistent units.

Broken (cloud cover)

This is a description of a sky cover of .6 to .9 (5/8 to 7/8)

Concentration (mg/m^3)

This is the quantity of a vapor or aerosol suspended in a volume of air.

Peak concentration

This term is used to describe the maximum concentration at a given distance that will result from a variable passing field.

Deposition density (mg/m^2)

This is the density of liquid or particulate contaminate that is deposited on the ground. It is employed as an assessment index and has been related to the percutaneous dose. In the current form of this relation, the percutaneous dose equals 1.62 times the deposition density raised to the 0.8 power. This relation has been derived from the short-range fallout from explosive munitions.

Dosage ($mg/min/m^3$)

Dosage is the integration of concentration in mg/m^3 and time in minutes, also referred to as Ct. This is a mathematical concept that makes a useful exposure index to vapors and small aerosols that can be absorbed by inhalation. When the dosage is multiplied by a breathing rate and retention efficiency, the result is an inhaled dose.

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Total dosage	This is the concentration time integral accumulated over the time of passage of the total cloud.
Partial dosage	If an evasive action is possible, such as donning a mask or moving out of the path of the cloud, then the exposure is to a partial dosage that is calculated from the time of release to the time the evasive action is complete. Thus, if the evasive action is accomplished in time t, the partial dosage: $D(t) = 0$ for $x > ut + 3 SX$, where SX is the standard deviation of the downwind dimension of the cloud, and u is the windspeed.
Dose (mg)	Dose is the quantity of a substance ingested into the body or placed on the body surface or clothing.
Inhaled dose	This is the quantity absorbed by the body by inhalation.
Intravenous dose	This is the amount reaching the blood stream.
Percutaneous dose	This is the amount applied to clothing or skin, or both.
Downwind length (m)	This is the length in the downwind direction across the surface of the spill. Like the evaporation time, this is assumed to be constant over the period of evaporation.
Evaporation time (min)	This is the time from the beginning of a spill to the total containment or neutralization of the agent. The model employed in SEVP2 assumes that the rate of release is constant over this period and thus is a safe-sided estimate of the total amount released.
Inhalation-deposition	When a substance with low volatility is released by explosion, both vapor and aerosol are produced. If the aerosol impacts on clothing or the skin and is not removed, a fraction will penetrate the skin and add to the dose that the body may have accumulated from inhalation. These are additive at the intravenous level and thus the intravenous dose, D_I, is the response index.
Mixing layer (m)	This layer is the region above the surface where mixing tends to approach uniformity. If travel proceeds for a sufficient distance, the vertical distribution tends to become uniform within this layer. Two forms of the mixing layer are considered in this report. The best defined of these is formed by an elevated temperature inversion that forms a cap to vertical diffusion. This cap is modeled as a reflective surface that would

produce multiple reflections to approach this uniformity. The other form of the mixing boundary is the result of the inertial forces acting on the eddies formed by the surface friction layer. This has been extended from the surface itself to objects on the surface and even the terrain which would affect this mixing. The same model is used for predictive purposes. Thus, this second category is achieved by entering a value that will approximate the inertial layer. (See Table 5.)

Overcast (cloud cover)	This is the description of a sky cover of 1.0 (8/8).
Rawinsonde (radiosonde)	This is balloon-borne instrumentation that is capable of measuring and transmitting the wind speed and direction, temperature, pressure, and humidity aloft during its ascension; analysis of this information can provide stability characteristics for various layers of the atmosphere.
Scattered (cloud cover)	This is a description of a sky cover of .1 to .5 (1/8 to 4/8).
Skin penetration factor	This factor is the ratio of intravenous dose to percutaneous dose. The skin penetration factor is defined for a specific type of exposure and a specific type of clothing.
Source sigmas (m)	These are characteristic dimensions of the source cloud. These are stated for the three directions X,Y, and Z and are expressed as the standard deviations (SXS, SYS, SZS). Through the diluting process of diffusion, the cloud is approximated as a Gaussian distribution moving with the wind and expanding.
Source strength (mg)	This is the quantity airborne. This release can occur instantaneously as with an explosive release or over a period of time as from a spill.
Source time (min)	This is the period of time over which the substance is emitted into the air. Zero is specified for an instantaneous release and infinity (1E36) for a continuous release.
Subsidence inversion	This is a temperature inversion produced by the warming of a layer of descending air and most frequently associated with a large high-pressure system. The inversion will have its base at some point above the ground and is enhanced by vertical mixing in the layer of air below. This type of inversion is often very persistent and frequently produces conditions requiring air pollution advisories.

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Surface inversion (radiation inversion)	This is a temperature inversion that has the earth's surface as its base. It is an increase of temperature with height beginning at the ground, a very stable layer of air in contact with the ground, a phenomenon that is established during nighttime hours and enhanced by clear skies and light winds.
Time after release (min)	A large component of the dosage computed by program HD42 is derived from the evaporation of the liquid splash. Thus, the dosage at the time of assessment is dependent on the amount that has evaporated to that time. This adjustment is contained within the model.
Two-minute correction	It has been shown that the dosage of GB or VX vapor required to produce a given physiological effect (with a constant breathing rate) is dependent on the time of accumulation. Thus, the total dosage is not an adequate index for long exposures (>2 min). Since the time of exposure is dependent on the size of the cloud, which changes with downwind distance, a correction has been developed for the diffusion model that converts the accumulated dosage at any point to the equivalent 2-minute dosage and thus permits the 2-minute value to be used as an index. The 2-minute correction is used for GB and VX vapor except when the no-effects (or lesser physiological effects) level is being considered.

APPENDIX E

PROGRAM LISTING

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HDS3.FOR

```
 1  C  HAZARD DISTANCE / MASTER PROGRAM / C.G.WHITACRE
 2  C  ADAPTED TO MS-FORTRAN BY J.H.GRINER III AND RICHARD L. ZUM BRUNNEN
 3        CHARACTER*1 IST,MTC,AA1,AB1
 4        CHARACTER*2 AGN,UM,AGNT,AA2,WT
 5        CHARACTER*3 PNU,PNUT,PNUC,MUN,MUNT,REL,RELT,LOC,LOCT,SEA,SEAT,
 6       1PRTT,SUR
 7        CHARACTER*12 ADH
 8        CHARACTER*20 APRT
 9        COMMON NQI,QT(6),TWL(6),D(10),DL(10)
10        COMMON PR(1),DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
11       1BETA,SZ100,Z,RC,V,QS
12        COMMON TEVP,SA,FL,FMW,FMV,VP,BP
13        COMMON HS,DS,TSC,VS,RDE,FP,HK,CR
14        COMMON SLA,SLO,CC,CH,AE,PMM,Z0
15        COMMON LOCT(1),SEAT,MUNT,AGNT,AA1,REL,MTC,AA2,SUR,WT,AB1,ADH,ADR,
16       1AD2
17        COMMON IPR(1),ND,IPO,I2MC,IMA,IPC,IMM,IDD,IHR,NOV,INP,MRL,NMU,ID2,
18       1IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
19        DIMENSION MUN(10),QF(10,3),SYSM(10),SZSM(10),AGN(18),D1(3,17)
20        DIMENSION FMWT(17),IST(11),LOC(12),SEA(4),HMLT(6,4,11),PMMT(12),
21       1PNU(77),J(67),K(67),RELT(10),PNUC(16),QTS(6)
22  $INCLUDE:'A:HMLMDR1.FOR'
23        DATA RELT/'INS','EVP','SEM','VAR','STK','STJ','FLS','FIR','IGL',
24       1'EVS'/
25        DATA AGN/'GB','VX','HD','AC','CG','CK','GA','GD','GF','H1','H3',
26       1'HT','LL','HY','UD','BZ','DM','NA'/
27        DATA PNUC/'ALL','STP','RST','INP','GTO','RSN','NQI','SMC','SMD',
28       1'SMP','RUN','TAB','???','DSP','PEE','VDP'/
29        DATA PNU/'TIM','DLX','HTS','HML','SXS','SYS','SZS','TMC','WND',
30       1'BRT','SKF','TMP','ALF','SYR','BTA','SZR','SMH','REF','SEV','QQQ',
31       2'TEV','ARE','LEN','FMW','FMV','VAP','BPT','HST','DST','TST','VST',
32       3'RDE','FRO','HRL','CRD','SLA','SLO','CCT','CHT','SUN','PMM','ZZO',
33       4'LOC','SEA','MUN','AGN','REL','STB','SUR','WOO','HLD','RLS','AD3',
34       5'IRT','NDI','OPO','2MC','IMA','OPC','IMM','IDD','HRS','NOV','INP',
35       6'MNR','NMU','NCI','IDE','IHT','  IM','  IR','  IL','IRL','ISM','IVD',
36       7'K33','K42'/
37        DATA J/1,7*0,1,2*0,1,7*0,8*1,8*0,6*1,0,8*1,9*0,3*1,0,1,0,1,0/
38        DATA MUN/'105','155','81N','500','750','M55','525','139','M23',
39       1'4.2'/
40        DATA IST/'A','B','C','D','E','F','N','I','U','S','W'/
41        DATA LOC/'AAD','DPG','EWA','JHI','LBG','NAP','PBA','PAD','RMA',
42       1'UAD','EUR','NDF'/
43        DATA SEA/'WIN','SPR','SUM','FAL'/
44        DATA I3,I4,I5/42,11,24/
45        WRITE (*,*) '  ------------------------------------'
46        WRITE (*,*) '  \ DOWNWIND HAZARD PROGRAM D2PC \'
47        WRITE (*,*) '  ------------------------------------'
48  1     DO 2 I=1,74
49        QT(I)=0.
50  2     CONTINUE
```

```
51        DO 3 I=1,11
52        LOCT(I)='   '
53    3   CONTINUE
54        DO 4 I=1,22
55        IPR(I)=0
56    4   CONTINUE
57        TIVCH=1.E36
58        DXT=10.
59        Z=0.
60        NMU=1
61        FNMU=1.
62        RC=1.
63        V=0.
64        BR=25.
65        SF=.022
66        DO 5 I=1,67
67        K(I)=0
68    5   CONTINUE
69        ND=0
70        CALL DEF (0,IRT)
71  C     1. NOVICE LEVEL
72        WRITE (*,*) '     TYPE ? FOR DEFINITIONS'
73    6   CALL DEF (1,IRT)
74        IF (IRT.EQ.0) READ (*,'(BN,I5)',ERR=10) NOV
75        IF (NOV.GT.2) CALL DEF (39,IRT)
76        IF (NOV.GT.(-1)) GO TO 7
77        CALL DEF(80,IRT)
78        READ(*,93)LOCT(1),SEAT,MUNT,AGNT,REL,MTC,US
79    7   UT=US
80  C     2. LOCATION
81        CALL DEF (2,IRT)
82        IF (IRT.EQ.0) READ (*,'(A3)') LOCT(1)
83        DO 8 IL=1,12
84        IF (LOCT(1).EQ.LOC(IL)) GO TO 11
85    8   CONTINUE
86        WRITE (*,9)
87    9   FORMAT (' LOCATION NOT DEFINED')
88        CALL DEF (42,IRT)
89        GO TO 7
90   10   CALL DEF (41,IRT)
91        GO TO 6
92  C     3. SEASON
93   11   IF (IL.EQ.12) GO TO 14
94        CALL DEF (3,IRT)
95        IF (IRT.EQ.0) READ (*,'(A3)') SEAT
96        DO 12 IS=1,4
97        IF (SEAT.EQ.SEA(IS)) GO TO 13
98   12   CONTINUE
99        CALL DEF (43,IRT)
100       GO TO 11
101  13   IF (K(41).EQ.0.AND.IL.NE.12) PMM=PMMT(IL)
102       IF (IL.NE.12) GO TO 15
103 C     4. HEIGHT OF MIXING LAYER
104  14   CALL READA (4,IRT,IA,HML)
105       IF (IRT.LT.0) GO TO 14
```

```
106   15    IDEP=0
107         IF (K(3).EQ.0) HT=0.
108         IF (K(57).EQ.0) I2MC=0
109         INQ=0
110         IMTCH=0
111  C      5. MUNITION TYPE
112   16    CALL DEF (5,IRT)
113         IF (IRT.EQ.0) READ (*,'(A3)') MUNT
114         IF (MUNT.NE.'???') GO TO 17
115         CALL DEF (45,IRT)
116         GO TO 16
117   17    DO 18 IMU=1,10
118         IF (MUNT.EQ.MUN(IMU)) GO TO 19
119   18    CONTINUE
120         INQ=1
121  C      6. AGENT TYPE
122   19    CALL DEF (6,IRT)
123         IF (IRT.EQ.0) READ (*,'(A2)') AGNT
124         IF (AGNT.NE.'??') GO TO 20
125         CALL DEF (46,IRT)
126         GO TO 19
127   20    DO 21 IA=1,18
128         IF (AGNT.EQ.AGN(IA)) GO TO 22
129   21    CONTINUE
130         IA=18
131  C      8. RELEASE TYPE
132   22    CALL DEF (8,IRT)
133         IF (IRT.EQ.0) READ (*,'(A3)') REL
134         IF (REL.NE.'???') GO TO 23
135         CALL DEF (48,IRT)
136         GO TO 22
137   23    DO 24 IR=1,10
138         IF (RELT(IR).EQ.REL) GO TO 25
139   24    CONTINUE
140         WRITE (*,*) ' RELEASE NOT DEFINED'
141         CALL DEF (48,IRT)
142         GO TO 22
143  C      9. STABILITY TYPE
144   25    CALL DEF (9,IRT)
145         IF (IRT.EQ.0) READ (*,'(A1)') MTC
146         IF (MTC.NE.'?') GO TO 26
147         CALL DEF (49,IRT)
148         GO TO 25
149   26    DO 27 IM=1,11
150         IF (MTC.EQ.IST(IM)) GO TO 28
151   27    CONTINUE
152         WRITE (*,*) ' STABILITY NOT DEFINED'
153         CALL DEF (49,IRT)
154         GO TO 25
155   28    IF (IMTCH.EQ.1) GO TO 29
156  C      10. WINDSPEED
157         CALL READA (10,IRT,IA,US)
158         IF (IRT.LT.0) GO TO 28
159   29    UT=US
160         IF (IM.EQ.10) CALL STAB (US,IM,IL,IMM,IDD)
```

```
161         IF (IM.EQ.11) CALL WOODS (UT,ALFA,SY100,BETA,SZ100,WT)
162         IF (IM.NE.9) GO TO 30
163  C      11. ALF,SYR,BTA,SZR
164         CALL DEF (11,IRT)
165         IF (IRT.EQ.0) READ (*,*) ALFA,SY100,BETA,SZ100
166    30   IF (IMTCH.EQ.1) GO TO 83
167         IF (IA.EQ.18) GO TO 34
168         IF (K(24).EQ.0) FMW=FMWT(IA)
169         IF (IA.LE.2.AND.K(57).EQ.0) I2MC=2-K(57)
170         IF (K(55).EQ.1.OR.K(67).GT.0) GO TO 32
171         DO 31 I=1,3
172         D(I)=D1(I,IA)
173    31   CONTINUE
174         ND=3
175         IRL=1
176         IF (K(65).EQ.0) MRL=0
177    32   IF (IA.EQ.2.AND.REL.EQ.'INS') GO TO 34
178         WRITE (*,33) (D(I),I=1,ND)
179    33   FORMAT (' DI=',10F8.1)
180    34   IF (IR.LT.4.OR.IR.EQ.10) NQI=1
181         GO TO (35,35,48,48,43,43,43,43,95,35), IR
182    35   IF (INQ.EQ.0) GO TO 37
183  C      7. SPILL OR AIRBORNE SOURCE
184    36   CALL READA (7,IRT,IA,QS)
185         IF (IRT.LT.0) GO TO 36
186         GO TO 40
187    37   IF (IA.GT.3) GO TO 38
188         IF (QF(IMU,IA).GT.0.) GO TO 39
189    38   WRITE (*,*) ' MUNITION-AGENT NOT DEFINED'
190         GO TO 36
191    39   IF (K(20).EQ.0) QS=QF(IMU,IA)
192    40   QT(1)=QS*FNMU
193    41   IF ((IR.EQ.1.AND.IA.EQ.3).OR.IR.EQ.2.OR.IR.EQ.10) WRITE (*,42)
194         IF (IR.NE.1) GO TO 43
195         IF (IA.EQ.2.OR.IA.GT.3.OR.INQ.EQ.1) GO TO 44
196  C      12. TEMPERATURE
197    42   FORMAT (5X,'SURFACE')
198    43   IF (IR.EQ.9) GO TO 48
199         CALL READA (12,IRT,IA,TMP)
200         IF (IRT.LT.0) GO TO 41
201    44   IF (IR.GT.2.AND.IR.LT.10) GO TO 48
202         IF (IR.EQ.2.OR.IR.EQ.10) GO TO 51
203         TWL(1)=.08
204         IF (K(6).EQ.0.AND.INQ.EQ.0) SYS=SYSM(IMU)
205         IF (K(7).EQ.0.AND.INQ.EQ.0) SZS=SZSM(IMU)
206         IF (K(5).EQ.0.AND.INQ.EQ.0) SXS=SYS
207         IF (IA.EQ.2) GO TO 46
208         IF (IA.NE.1) GO TO 52
209         IF (INQ.EQ.1) GO TO 52
210         IF (QF(IMU,1).GT.4.5E7) GO TO 45
211         QT(1)=QT(1)*(.5+(.00782*TMP))
212         GO TO 52
213    45   QT(1)=QT(1)*(.5_+(.0022*TMP))
214         GO TO 52
215    46   IDEP=1
```

```
216          D(1)=.44
217          D(2)=1.76
218          D(3)=4.
219          WRITE (*,47) D(1),D(2),D(3)
220    47    FORMAT (' EDI='3F5.2)
221          IF (IMU.NE.9) GO TO 52
222          IDEP=2
223          GO TO 52
224  C  13. NQI,Q(),QT() OR Q,QT
225    48    CALL DEF (13,IRT)
226          IF (IRT.EQ.1) GO TO 49
227          IF (IR.NE.3) READ (*,*) NQI,(QTS(I),TWL(I),I=1,NQI)
228          IF (IR.EQ.3) READ (*,*) QTS(1),TWL(1)
229    49    DO 50 I=1,NQI
230          QT(I)=QTS(I)*FNMU
231    50    CONTINUE
232          GO TO 52
233    51    IF (IR.EQ.2) CALL EVAP (AGNT,QT(1),PMM,UT,TMP,TWL(1),SUR,IL)
234          IF (IR.EQ.10) CALL EVAP(AGNT,QT(1),PMM,.01,TMP,TWL(1),SUR,IL)
235          SXS=FL/3.
236          SYS=SA/(FL*3.)
237          SZS=.1
238    52    IF (IM.GT.6.AND.IL.NE.12.AND.K(4).NE.1) HML=HMLT(4,IS,IL)
239          IF (IM.LE.6.AND.IL.NE.12.AND.K(4).NE.1) HML=HMLT(IM,IS,IL)
240    53    ISM=0
241    54    ISM=3
242          IF (HML.EQ.0.) WRITE (*,55)
243    55    FORMAT (' DEFINE HML')
244          WRITE (*,56)
245    56    FORMAT (' ALL OTHER INPUT')
246    57    IER=1
247          READ (*,'(A3,1X,A20)') PNUT,APRT
248          READ (APRT,'(BN,F20.0)',ERR=59) PRT
249          IER=0
250          DO 58 I=1,16
251          IF (PNUT.EQ.PNUC(I)) GO TO 75
252    58    CONTINUE
253  C
254    59    DO 66 I=1,67
255          IF (PNUT.NE.PNU(I)) GO TO 66
256          IF (I.LT.43.OR.I.GT.53) GO TO 62
257          READ (APRT,'(A3)') PRTT
258          IF (I.LT.51.OR.I.GT.52) GO TO 63
259          DO 60 II=1,67
260          IF (PRTT.EQ.PNU(II)) GO TO 61
261    60    CONTINUE
262    61    K(II)=52-I
263          IF (II.EQ.57.AND.I2MC.NE.0) I2MC=I-50
264          GO TO 57
265    62    IF (IER.EQ.0) GO TO 63
266          READ (APRT,'(A2,BN,F18.0)',ERR=54) UM,PRT
267          CALL UNT (UM,IA,PRT)
268    63    IF (I.LT.43) PR(I)=PRT
269          IF (I.GT.42.AND.I.LT.53) LOCT(I-42)=PRTT
270          IF (I.GT.53) IPR(I-53)=PRT
```

```
271         IF (I.EQ.66) FNMU=PRT
272         JSM=JSM+J(I)
273         IF (I.EQ.55.OR.I.EQ.67) GO TO 68
274         IF (I.EQ.58) K(67)=PRT
275         IF (I.EQ.58.AND.PRT.GT.0.AND.PRT.LT.4) WRITE (*,64)
276    64   FORMAT (' DEFINE NCI')
277         IF (I.EQ.9) US=UT
278         IF (I.EQ.47.AND.PRTT.EQ.'SEM'.OR.PRTT.EQ.'VAR') CALL DEF (-13,IRT)
279         IF (I.EQ.20.AND.IR.GT.2) WRITE (*,65)
280    65   FORMAT (' DEFINE NQI')
281         GO TO 57
282    66   CONTINUE
283         WRITE (*,67)
284    67   FORMAT (' SYM NOT FOUND')
285         GO TO 54
286    68   IF (IMA.EQ.0) WRITE (*,69)
287    69   FORMAT (' INPUT: DI()S')
288         IF (IMA.EQ.0) GO TO 71
289         WRITE (*,70)
290    70   FORMAT (' INPUT: CI()S')
291         ND=PRT
292    71   READ (*,*) (D(I),I=1,ND)
293         MRL=0
294         IRL=0
295         GO TO 54
296    72   NQI=PRT
297         WRITE (*,73)
298    73   FORMAT (' INPUT: Q()(MG), TQ()(MIN)')
299         READ (*,*) (QT(I),TWL(I),I=1,NQI)
300         DO 74 I=1,NQI
301         QTS(I)=QT(I)
302    74   CONTINUE
303         GO TO 54
304    75   NIQ=(-PRT)
305         IF (I.EQ.13) NIQ=0
306         IF (I.EQ.14) NIQ=PRT
307         IF (I.GT.11.AND.I.LT.15) CALL DEF(40,NIQ)
308         IF (I.EQ.16) IVD=PRT
309         IF (I.EQ.4.OR.I.EQ.5) CALL DEF (NIQ,IRT)
310         GO TO (77,89,1,59,6,7,72,76,76,76,78,54,54,54,90,57), I
311    76   ISM=I-8
312         IF (I.EQ.10) GO TO 57
313         CALL DDS
314         GO TO 54
315    77   IF (JSM.GT.0) GO TO 7
316    78   IF (ND.GT.0) GO TO 80
317         IF (IMA.EQ.0) WRITE (*,79)
318    79   FORMAT (' DEFINE NDI')
319         IF (IMA.GT.0) WRITE (*,64)
320         GO TO 57
321    80   IF (IMA.NE.2.OR.IA.NE.18) GO TO 81
322  C      14. MOLECULAR WEIGHT
323         CALL DEF (14,IRT)
324         IF (IRT.EQ.0) READ (*,*) FMW
325    81   IF ((FNMU-NMU).GT.0.) GO TO 96
```

```
326          WRITE (*,82) NMU,MUNT,AGNT,REL,UT,TMP,LOCT(1),SEAT,MTC
327    82    FORMAT (//I5,' MUN:',A3,2X,'AGN:',A2,2X,'REL:',A3,2X,'WND=',F4.1,
328         1'(M/S)',2X,'TMP=',F4.1,'(C)',2X,A3,'-',A3,1X,'STB:',A1)
329    98    IF (IA.EQ.3.AND.IR.EQ.1) IDEP=-1
330    83    IF (IR.LE.4.OR.IR.GT.8) GO TO 84
331          CALL PLRS (UT,TMP,PMM,IL,IM,IR,0.,HT,HML,IPC,IRTP)
332    84    IF (HT.GT.HML) WRITE (*,85)
333    85    FORMAT (' HEIGHT OF RELEASE IS GREATER THAN MIXING LAYER')
334          IF (QT(1).EQ.0.) WRITE (*,86)
335    86    FORMAT(' THE SOURCE STRENGTH IS SET AT ZERO')
336          IF (UT.EQ.0.) WRITE (*,88)
337          IF (HML.EQ.0..OR.HT.GT.HML.OR.QT(1).EQ.0..OR.UT.EQ.0.) GO TO 54
338          IF (IVD.EQ.1.AND.IL.EQ.12) GO TO 91
339          IF (IDEP.EQ.-1.AND.IM.EQ.11) GO TO 99
340          IF (IVD.EQ.1.AND.IM.GT.6) GO TO 94
341    92    K33 = K(33)
342          K42 = K(42)
343          IF (IMA.EQ.0) CALL DDS
344          IF (IMA.GT.0) CALL CDS
345          IF (IMTCH.EQ.1) GO TO 87
346          IF (IPR(1).EQ.0) GO TO 53
347          CALL DEF ((-IPR(1)),IRT)
348          GO TO 7
349    87    WRITE (*,*) ' INPUT: STB'
350          READ (*,'(A1)') MTC
351          WRITE(*,*)' INPUT: WND, HML, TMC'
352          READ (*,*) US,HML,TIVCH
353          GO TO 26
354    88    FORMAT (' DEFINE WND')
355    90    IF (PRT.EQ.1.) WRITE(*,'(1P2F10.3)')(QT(I),TWL(I),I=1,6)
356          IF (PRT.EQ.2.) WRITE(*,'(1P2E10.3)')(D(I),DL(I),I=1,10)
357          IF (PRT.EQ.3.) WRITE(*,'(2(A5,1PE10.3))')
358         $(PNU(I),PR(I),I=1,13)
359          IF (PRT.EQ.4.) WRITE(*,'(A5,A4)')
360         $(PNU(I+42),LOCT(I),I=1,14)
361          IF (PRT.EQ.5.) WRITE(*,'(2(A5,I6))')
362         $(PNU(I+53),IPR(I),I=1,15)
363   C THE FOLLOWING CALL IS A DUMMY CALL THE ONLY IMPORTAN VARIABLE IS
364   C LAST ONE (4).
365          IF (PRT.EQ.6) CALL VDPL(DD,DD,ID,ID,ID,ID,DD,DD,DD,DD,DD,DD,
366         1DD,DD,DD,DD,DD,DD,DD,4)
367          GO TO 54
368   C      29. FROST PROFILE EXP AND ROUGHNESS LENGTH
369    91    CALL DEF(29,IRT)
370          IF (IRT.EQ.0) READ(*,*) FP,ZO
371          GO TO 92
372    93    FORMAT(A3,1X,A3,1X,A3,1X,A2,1X,A3,1X,A1,1X,BN,F10.0)
373    94    WRITE(*,*) ' VAPOR DEPLETION ONLY DEFINED FOR STABILITIES A-F'
374          GO TO 53
375    95    CALL IGLO(QTS,TWL,NQI,IMU,IA,IR)
376          IF (IR.EQ.9) GO TO 53
377          GO TO 49
378    96    WRITE(*,97) FNMU,MUNT,AGNT,REL,UT,TMP,LOCT(1),SEAT,MTC
379    97    FORMAT(//F5.2,' MUN:',A3,2X,'AGN:',A2,2X,'REL:',A3,2X,'WND=:',
380         $F4.1,'(M/S)',2X,'TMP=',F4.1,'(C)',2X,A3,'-',A3,1X,'STB:',A1)
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381        GO TO 98
382   99   WRITE(*,*) ' INSTANTANEOUS RELEASE OF HD IN WOODS NOT DEFINED'
383        GO TO 53
384   89   STOP
385        END
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EVAP3.FOR

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1   C   EVAPORATION FROM A PUDDLE W/AREA W/STILL AIR /CGW
2           SUBROUTINE EVAP (AGNT,QT,PMM,U,TC,TS,SUR,IL)
3           COMMON EDM(52),QS,TEVP,SA,FL,FMWT,FMVT,VP,BPT,ED2(50)
4           CHARACTER*3 SUR
5           CHARACTER*2 AGN,AGNT
6           DIMENSION AGN(25),FMW(25),FMV(25),BP(25),A(26),B(26),C(26),FP(26)
7           DATA AGN/'GB','VX','HD','AC','CG','CK','GA','GD','GF','H1','H3',
8          1'HT','LL','HY','UD','QL','DF','DC','TC','PR','IP','ZS','KB',
9          1'DM','DM'/
10          DATA FMW/140.1,267.4,159.1,27.02,98.92,61.48,162.18,182.18,180.2,
11         1170.08,204.54,189.4,207.35,32.05,60.1,235.3,100.0,132.9,119.0,
12         179.1,60.09,46.07,145.7,0.,0./
13          DATA FMV/150.3,342.2,149.7,39.6,70.4,51.4,188.,211.4,196.8,184.3,
14         1202.8,150.,130.1,34.5,81.7,332.37,81.93,105.4,79.5,89.3,81.9,
15         162.3,208.0,0.,0./
16          DATA BP/431.,571.,490.,298.7,281.4,285.8,518.,471.,512.,467.,529.,
17         1501.,463.,386.6,337.1,517.7,372.7,439.6,348.8,388.3,355.2,
18         1351.3,463.1,0.,0./
19          DATA A/8.5916,7.281,7.47009,7.7446,7.460,8.6642,8.305,10.1174,
20         110.8872,9.0715,8.986,0.,6.40361,9.0347,8.2223,6.52001,7.5444,
21         17.2442,7.18757,7.05878,7.74144,8.17753,8.6883,0.,0.,0./
22          DATA B/-2424.5,-2072.1,-1935.47,-1453.1,-1289.2,-1654.6,-2820.,
23         1-3136.,-3590.5,-2890.7,-3232.,0.,-1237.037,-2348.18,-1799.31,
24         1-1428.57,-1577.8,-1669.7,-1384.18,-1385.39,-1360.183,-1630.863,
25         1-2663.33,0.,0.,0./
26          DATA C/273.,172.5,204.2,273.,273.,273.,273.,273.,273.,273.,
27         1273.2,273.,155.2,273.,273.,147.8,238.6,216.1,245.567,216.338,
28         1197.593,229.581,268.48,0.,0.,0./
29          DATA FP/-56.,-51.,14.45,-13.3,-128.,-6.9,-50.,-42.,-30.,-34.,
30         1-3.7,-14.,-18.,1.4,-58.,-45.6,-36.9,33.,-105.,-42.,-85.8,-110.5,
31         1-39.,0.,0.,0./
32          IF(U.EQ.0) U=.03
33          DO 10 IA=1,25
34          IF(AGNT.EQ.AGN(IA)) GO TO 15
35      10  CONTINUE
36          IA=26
37      15  IF (IL.NE.12) GO TO 40
38   C      16. ATMOSPHERIC PRESSURE
39      20  CALL READA (16,IRT,IA,PMM)
40          IF (IRT.LT.0) GO TO 20
41   C      17. SURFACE CODE
42      40  CALL DEF(17,IRT)
43          IF(IRT.EQ.0) READ(*,'(A3)') SUR
44   C      18. TIME OF EVAPORATION
45      60  CALL READA (18,IRT,IA,TEVP)
46          IF (IRT.LT.0) GO TO 60
47          P=PMM/760.
48          TA=TC+273.
49          RHOA=.3487*P/TA
50          FMUA=EXP(4.36+.002844*TA)*1.E-6
```

```
51        SCD=FMUA/RHOA
52        IF (SUR.EQ.'GRA') GO TO 120
53        IF (SUR.EQ.'NPR') GO TO 130
54        IF (SUR.EQ.'NDF') GO TO 80
55        WRITE(*,70)
56    70  FORMAT (' SURFACE CODE NOT DEFINED')
57        CALL DEF (57,IRT)
58        GO TO 40
59  C     19. AREA OF WETTED SURFACE
60    80  CALL READA (19,IRT,IA,SA)
61        IF (IRT.LT.0) GO TO 80
62  C     20. LENGTH OF SURFACE DOWNWIND
63   100  CALL READA (20,IRT,IA,FL)
64        IF (IRT.LT.0) GO TO 100
65        GO TO 150
66   120  SA=.153E-6*QT
67        GO TO 140
68   130  SA=1.21E-6*QT
69   140  FL=SA**.5
70   150  IF (IA.LT.26.AND.IA.NE.12) GO TO 180
71  C     21. FMW,FMV,VAP,BPT
72        CALL DEF (21,IRT)
73        IF (IRT.EQ.0) READ(*,*) FMWT,FMVT,VP,BPT
74        IF (IRT.EQ.0) IVP=1
75        IF (VP.GT.0.) GO TO 170
76        WRITE(*,*) ' INPUT ANTOINE CONSTANTS: A,B,C, FP(DEG C)'
77        READ(*,*) A(26),B(26),C(26),FP(26)
78        IVP=(-1)
79   170  IF (IVP) 185,185,205
80   180  FMWT=FMW(IA)
81        FMVT=FMV(IA)
82        BPT=BP(IA)
83   185  IF (TC.GT.FP(IA)) GO TO 200
84        WRITE(*,190)
85   190  FORMAT (' TEMPERATURE LESS THAN FREEZING')
86        TS=1.E36
87        QT=0.
88        RETURN
89   200  VP=10.**(A(IA)+B(IA)/(TC+C(IA)))
90   205  IF (VP.LT.PMM) GO TO 230
91        WRITE(*,210)
92   210  FORMAT (' TEMPERATURE GREATER THAN BPT')
93        TS=.1
94        RETURN
95   230  TS=TEVP
96        FD=TA**1.5*(.03448+1./FMWT)**.5/P
97        D=FD*.0043/(3.1034+FMVT**.3333)**2
98        RE=FL*U/SCD*1.E4
99        FJM=.036/RE**.2
100       IF (RE.LE.20000.) FJM=.664/RE**.5
101       GM=U*RHOA*3.448
102       FKG=GM*FJM/(SCD/D)**.667
103       EVR=FKG*FMWT*VP/PMM*6.E8
104       AK=.1025*TA/BPT**.5
105       OM=(1.075*AK**(-.1615))+2.*(10.*AK)**(-.74*ALOG10(10.*AK))
```

```
106        CD=1.18*FMVT**.3333
107        DS=FD*.00205/(OM*((3.711+CD)/2.)**2)
108        FLC=(4.*SA/3.14159)**.5
109        RES=FLC*.03/SCD*1.E4
110        EVRS=292.*(1.+.51*RES**.5*(SCD/DS)**.3333)*ALOG(1./(1.-VP/PMM))*
111       1FMWT/TA*DS/FLC*2./3.14159*1000.
112        IF (EVRS.GT.EVR) EVR=EVRS
113        IF (EVRS.EQ.EVR) WRITE(*,240)
114    240 FORMAT (' STILL AIR')
115    250 FORMAT(1X,A3,'  EVR='1PE9.3,'(MG/MIN-SQ M)  AREA='E9.3,'(SQ M)',
116       1' VPR='E9.3/,' Q='E9.3,'(MG)  '3HQ'=E9.3,'(MG)  ',
117       2'  TEV='E9.3,'(MIN)')
118        Q=SA*TEVP*EVR
119        TS=TEVP
120        IF (Q.LE.QT) GO TO 260
121        TS=QT/EVR/SA
122        Q=QT
123    260 WRITE(*,250) SUR,EVR,SA,VP,QT,Q,TS
124        QT=Q
125        RETURN
126        END
```

```
37G3.FOR

1  C  AXIAL DOSAGE/ SEMI-CONT/ VAR SOURCE/ VAR MET ORG CGW
2         SUBROUTINE DDS
3         CHARACTER*1 ST,MTC,AA1,AB1
4         CHARACTER*2 AGNT,WT,AA2,CST,I2
5         CHARACTER*3 MUNT,REL,LOCT,SEAT,SUR,I3,I4,I5
6         CHARACTER*12 ADH,RL
7         COMMON NQI,QT(6),TWL(6),D(10),DL(10)
8         COMMON PR(1),DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
9        1BETA,SZ100,Z,RC,V,QS
10        COMMON DDM(12),FP,DDM1(8),Z0,LOCT(1),SEAT,MUNT,AGNT,AA1,REL,
11       $       MTC,AA2,SUR,WT,AB1,ADH,ADR,AD2
12        COMMON IPR(1),ND,IPO,I2MCS,IMA,IPC,IMM,IDD,IHR,NOV,INP,MRL,ID1,
13       1ID2,IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
14        DIMENSION SY100T(6),SZ100T(6),SY100I(6),ALFAT(6),BETAT(6),ST(11),
15       1SY100C(2,3),SZ20C(2,3),BETAC(2,3),TWLS(6),AR(10),Y(10),VF(2),CI(2)
16       2,S(2),RL(3),DS(31,2)
17        DATA ALFAT/1.,1.,1.,.9,.8,.7/
18        DATA BETAT/1.4,1.,.9,.85,.8,.75/
19        DATA SY100I/9.,6.33,4.8,4.,3.,2./
20        DATA SY100T/27.,19.,12.5,8.,6.1,4./
21        DATA SZ100T/14.,11.,7.5,4.5,3.5,2.5/
22        DATA SY100C/41.19,31.18,66.56,30.98,26.17,29.33/
23        DATA SZ20C/3.,1.652,.797,1.934,.705,1.242/
24        DATA BETAC/1.344,.755,1.218,.949,1.182,1./
25        DATA ST/'A','B','C','D','E','F','N','I','U','S','W'/
26        DATA VF,CI,S/.13,0,.454,.262,2.38,2.24/
27        DATA I4,I5/'EDI','EDS'/
28        DATA RL/'NO EFFECTS  ','NO DEATHS   ','1% LETHALITY'/
29        IF (ISM.GT.1) GO TO 2
30        DO 1 I=1,51
31     1  DS(I,2)=(DS(I,1)+DS(I,2))*ISM
32        RETURN
33     2  IF (IMTCH) 3,3,7
34     3  DX=DXT
35        DO 4 I=1,ND
36        AR(I)=0.
37     4  DL(I)=ALOG(D(I))
38        K=1
39        DLDG=1.
40        DLDGS=1.
41        X=0.
42        TWHML=HML+HML
43        IC=ND
44        MXLF=0
45        XX=0.
46        XY=0.
47        XZ=0.
48        XS=0.
49        DPMX=0.
50        IRTP=1
```

```
51          IF (IR.GT.4.AND.IR.L...8) IRTP=0
52          DPL=-87.5
53          DPLS=-87.5
54          I2MC=I2MCS
55          TQS=0.
56          QRMX=0.
57          SDEPL=1.
58          QTTL=0.
59          DO 5 I=1,NQI
60          QTTL=QTTL+QT(I)
61          TWLS(I)=TWL(I)*60.
62          QR=QT(I)/(TWLS(I)-TQS)
63          IF (QRMX.GT.QR) GO TO 5
64          QRMX=QR
65          TQ2=TWLS(I)
66          TQ1=TQS
67    5     TQS=TWLS(I)
68          TOMXS=(TQ2-TQ1)/2.+TQ1
69          IF (IDEP) 6,7,7
70    6     CALL HD42
71          IF (QT(1).EQ.0.) RETURN
72          GO TO 11
73    7     IMTCH=0
74          IF (IM.EQ.9.OR.IM.EQ.11) GO TO 11
75          IF (IM.LE.6) GO TO 9
76          IF (IM.LE.8) GO TO 10
77          WRITE (*,8)
78    8     FORMAT (' MET CODE NOT DEFINED')
79          RETURN
80    9     IF (TOMXS.LE.2.4) SY100=SY100I(IM)
81          IF (TOMXS.GT.2.4) SY100=SY100T(IM)
82          SZ100=SZ100T(IM)
83          ALFA=ALFAT(IM)
84          BETA=BETAT(IM)
85          GO TO 11
86    10    IF (UT.LE.2.235) I=1
87          IF (UT.GT.2.235.AND.UT.LE.4.47) I=2
88          IF (UT.GT.4.47) I=3
89          MC=IM-6
90          SY100=SY100C(MC,I)
91          SZ100=SZ20C(MC,I)*5**BETAC(MC,I)
92          ALFA=.5
93          BETA=BETAC(MC,I)
94    11    U=UT
95          XCH=1.E36
96          IF (TIVCH.NE.1.E36) XCH=U*TIVCH*60.+X
97          IF (X.LE.0.) X=1.
98          IF (SXS.GT.0.) XX=(SXS/.1522)**(1./.9294)-X
99          IF (SYS.GT.0.) XY=100.*(SYS/SY100)**(1./ALFA)-X
100         IF (SZS.GT.0.) XZ=100.*(SZS/SZ100)**(1./BETA)-X
101         WRITE (*,12)
102   12    FORMAT (/4X,'Q(MG)',3X,'TS(MIN)',2X,'HTS(M)',3X,'HML(M)',3X,
103         1'SXS(M)',3X,'SYS(M)',3X,'SZS(M)')
104         CST=ST(IM)
105         IF(IM.EQ.11) CST=WT
```

```
106          WRITE(*,13) QT(1),TWL(1),HT,HML,SXS,SYS,SZS,CST
107    13    FORMAT (1X,1PE9.3,6(1X,E8.2),2X,A2)
108          IF (NQI.EQ.1) GO TO 15
109          DO 14 I=2,NQI
110          WRITE(*,13) QT(I),TWL(I)
111    14    CONTINUE
112    15    IF (IVD.EQ.1) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,XCH,DP,
113         1DPA,SDEPL,1)
114          IF(IDEP.GE.1) WRITE(*,18) BR,SF
115          IF(I2MC.GT.0) WRITE(*,103)
116          IF(ISM.EQ.2) WRITE(*,105)
117          IF (IPO.LT.1.OR.IPO.EQ.4) GO TO 25
118          WRITE(*,16)
119    16    FORMAT (/3X,'ALFA',5X,'SYR',4X,'BETA',5X,'SZR',5X,'XY',6X,'XZ')
120          WRITE(*,17) ALFA,SY100,BETA,SZ100,XY,XZ,UT
121    17    FORMAT (1X,7(1PE8.2))
122    18    FORMAT (/' BRT=',F4.0,'    SKF=',1PE8.2)
123          I2='DP'
124          IF (IDEP.GT.0) I2='ED'
125          I3='   '
126          IF (I2MC.GT.0) I3='2MC'
127          IF (IPO.NE.3) GO TO 21
128          WRITE(*,19) (D(I),I=1,ND)
129    19    FORMAT(/6X,'DOSAGE CONTOURS',10F5.0)
130          WRITE(*,20) I2,I3
131    20    FORMAT(/7X,'X',7X,A2,A1,3X,'CONTOUR HALF-WIDTH')
132          GO TO 25
133    21    IF (IDEP.EQ.0) WRITE(*,24) I2,I3,I3
134          IF (IDEP.GT.0) WRITE(*,24) I2,I3,I3,I4,I5
135    24    FORMAT(/7X,'X',7X,A2,A1,7X,'RF',7X,A3,7X,A3,7X,A3)
136          IF (ISM.EQ.2) WRITE(*,100)
137    25    IF (X.GT.XCH) X=XCH
138          B=X/U
139          IIND=0
140          IF (IRTP.GT.0) GO TO 26
141          CALL PLRS (U,TMP,PMM,IL,IM,IR,X,HT,HML,IPC,IRTP)
142    26    DXA=DX
143          IF (X.GE.(DX*10.)) DX=DX*10.
144          DXA=DXA+DX
145          SX=.1522*(XX+X)**.9204
146          SY=SY100*((X+XY)*.01)**ALFA
147          SZ=SZ100*((X+XZ)*.01)**BETA
148          IF (IVD.EQ.1.AND.X.EQ.1) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,
149         1XCH,DP,DPA,SDEPL,2)
150          DP=0.
151          IF (I2MC.EQ.0) GO TO 27
152          A=1./(1.414*SX)
153          G=.7979*SX/U
154          H=.5/(SX*SX)
155          TSX=SX/U
156          IT=0
157          TT0=B+TOMXS
158          TT1=TT0-60.
159          TT2=TT1+120.
160    27    TSZSQ=SZ*SZ*2.
```

```
161       HPZ=HT+Z
162       HMZ=HT-Z
163       VT=V*X/U
164       FAC=0.
165       HML2=1.E36
166       ARG=(HMZ-VT)**2/TSZSQ
167       IF (ARG.LT.87.) FAC=FAC+EXP(-ARG)
168       ARG=(HPZ-VT)**2/TSZSQ
169       IF (ARG.LT.87.) FAC=FAC+RC/EXP(ARG)
170       ZFAC=0.
171       IF (HML.GT.1.E10.OR.MXLF.EQ.1) GO TO 30
172       DO 28 JJ=1,20
173       SMHML=TWHML*JJ
174       ARG=(SMHML-HPZ+VT)**2/TSZSQ
175       IF (NOV.EQ.4) WRITE(*,*) ' ARG',ARG
176       IF (ARG.GT.87.) GO TO 29
177       ZFAC=ZFAC+RC**(JJ-1)/EXP(ARG)
178       ARG=(SMHML-HMZ+VT)**2/TSZSQ
179       IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
180       ARG=(SMHML+HMZ-VT)**2/TSZSQ
181       IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
182       ARG=(SMHML+HPZ-VT)**2/TSZSQ
183    28 IF (ARG.LT.87.) ZFAC=ZFAC+RC**(JJ+1)/EXP(ARG)
184    29 IF ((FAC+ZFAC).NE.0.) HML2=(2.5066283*SZ)/(FAC+ZFAC)
185       IF (HML.GT.HML2.AND.(HML-HML2).LT.1) MXLF=1
186    30 RF=(FAC+ZFAC)/2.
187       IF (IIND) 33,33,31
188    31 TT0=B-TSX-TSX
189       TT1=TT0
190       TT3=B+TWLS(NQI)+TSX+TSX
191       TT3S=TT3
192       TT3=TT3-120.
193       DTT=(TT3-TT0)/30.
194       IF (DTT.LT.10.) DTT=10.
195       TT2=TT1+120.
196       DOS=0.
197       IF (DTT.LT.120.) GO TO 33
198    32 TT2=TT1+DTT
199    33 TWLT=0.
200       DLDP=0.
201       DO 63 ITWL=1,NQI
202       TS=TWLS(ITWL)-TWLT
203       IF (MXLF) 35,35,34
204    34 C=QT(ITWL)/(300.79539*U*TS*SY*HML)
205       GO TO 36
206    35 C=QT(ITWL)*RF/(376.991*U*TS*SY*SZ)
207    36 IF (I2MC.GT.0) GO TO 37
208       DP=DP+C*2.*TS
209       GO TO 63
210    37 T1=TT1-TWLT
211       IF (T1) 38,39,39
212    38 T1=0.
213    39 T2=TT2-TWLT
214       IF (T2) 63,63,40
215    40 I=3
```

```
216          PT1=T1
217          PT2=T2
218          P=T2-TS
219          R=T1-TS
220          IF (P) 42,42,41
221    41    IF (R) 44,43,43
222    42    I=1
223          GO TO 45
224    43    I=2
225          GO TO 45
226    44    T2=TS
227          R=0.
228    45    E=X-U*T2
229          EE=E*E
230          F=X-U*T1
231          FF=F*F
232          W=(T2-B)*ERFF(E*A)
233          CC=(T1-B)*ERFF(F*A)
234          ARG1=EE*H
235          ARG2=FF*H
236          IF (ARG1-82.6) 47,47,46
237    46    ARG1=0.
238          GO TO 49
239    47    ARG1=EXP(-ARG1)
240    48    ARG2=EXP(-ARG2)
241          GO TO 51
242    49    IF (ARG2-82.6) 48,48,50
243    50    ARG2=0.
244    51    DD=G*(ARG1-ARG2)
245          GO TO (52,54,52,54), I
246    52    QQ=(T2-T1)*ERFF(X*A)
247          XTERM=C*(QQ-W+CC+DD)
248          IF (I-3) 62,53,94
249    53    PART=XTERM
250          I=4
251          T2=PT2
252          T1=TS
253          GO TO 45
254    54    ARG3=X-U*P
255          ARG4=X-U*R
256          HH=(T2-B-TS)*ERFF(ARG3*A)
257          PP=(T1-B-TS)*ERFF(ARG4*A)
258          ARG3=(ARG3**2)*H
259          ARG4=(ARG4**2)*H
260          IF (ARG3-82.6) 56,56,55
261    55    ARG3=0.
262          GO TO 58
263    56    ARG3=EXP(-(ARG3))
264    57    ARG4=EXP(-(ARG4))
265          GO TO 60
266    58    IF (ARG4-82.6) 57,57,59
267    59    ARG4=0.
268    60    GG=G*(ARG3-ARG4)
269          XTERM=C*(HH-PP-W+CC-GG+DD)
270          IF (I-4) 62,61,94
```

```
271   61    T1-P11
272         I=3
273         XTERM-XTERM+PART
274   62    DLDP-DLDP+XTERM
275         TWLT-TWLS(ITWL)
276   63    CONTINUE
277         DPA-DP
278         IF (I2MC.EQ.0) GO TO 75
279         IF (IIND) 64,64,65
280   64    IIND-1
281         TDLDP-DLDP+0.
282         GO TO 31
283   65    DP-DP+DLDP
284         IF (IT) 66,56,67
285   66    IT-1
286         TT2C-TT2-TTO
287         GO TO 71
288   67    TT10-TT1-TTO
289         TT20-TT2-TT10
290         TT21-TT2-TT1
291         TT121-TT2C+TT2-TT1
292         TT10P-TT2C**.274
293         TT20P-TT121**.274
294         TT21P-TT21**.274
295         DELDC-.2696*(D0*(TT20P-TT10P))
296         IF (DELDC-DLDP) 69,68,70
297   68    TT2C-TT121
298         GO TO 71
299   69    DPC-DPS+DELDC
300         TT2C-(((DPC*TT20P)+((DLDP-DELDC)*TT21P))/DP)**3.6496
301         GO TO 71
302   70    TT2C-((DLDP/TT21)*TT20*TT20P)+((DPS-(DLDP/TT21)*TT10)*TT10P)
303         TT2C-(TT2C/DP)**3.6496
304   71    DPS-DP
305         D0-DP/(.2696*(TT2C**.274))
306         IF (DOS-D0) 72,72,73
307   72    TT2CS-TT2C+0.
308         DOS-D0
309   73    TT1-TT2
310         IF (TT2-TT3S) 32,74,74
311   74    DLDG-.2696*TT2CS**.274
312         IF (DLDG.LT.1.) DLDG-1.
313         DPA-DP
314         DP-DP/DLDG
315         IF (DP.LT.TDLDP) DP-TDLDP
316   75    IF (IDEP.LT.1) GO TO 76
317         DPA-DPA*VF(IDEP)
318         DOSI-DP*VF(IDEP)
319         DOSIS-QT(1)*SF*CI(IDEP)*(U/X)**S(IDEP)*1000/BR
320         DP-(DOSI+DOSIS)
321   76    IF (IVD.EQ.1) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,
322        1XCH,DP,DPA,SDEPL,3)
323         IF (K.LT.52) DS(K,1)-DP
324         IF (ISM.EQ.2) DP-DS(K,2)+DP
325         IF (DP.LE.0.) GO TO 83
```

```
326          DPL=ALOG(DP)
327          IF (XS.EQ.0..OR.DPL.GE.DPLS) GO TO 83
328          IND=1
329          IF (IC-MRL) 84,84,77
330    77    IF (DPMX.LT.D(IC)) GO TO 78
331          IF (DP.GT.D(IC).OR.DPLS.LT.DL(IC)) GO TO 84
332          XL=ALOG(X)
333          XLS=ALOG(XS)
334          XINT=EXP(XLS+(XL-XLS)*(DL(IC)-DPLS)/(DPL-DPLS))
335          IF (IVD.EQ.1) WRITE(*,'(F5.2)') SDEPL
336          IF (IRL.EQ.0) WRITE(*,101) XINT,D(IC)
337          IF (IRL.EQ.1) WRITE(*,102) XINT,RL(IC)
338    78    IF (D(IC).EQ.1.E36) WRITE(*,79)
339    79    FORMAT (' RESP NOT DEF')
340          IC=IC-1
341          IF (IC.GT.1.OR.I2MC.LT.2) GO TO 81
342          DPLS=ALOG(EXP(DPLS)*DLDGS)
343          DPL=ALOG(DP*DLDG)
344          I2MC=0
345          IF (IC.GT.MRL) WRITE(*,80)
346    80    FORMAT (' W/O 2-MINUTE CORRECTION')
347    81    IF (IC-MRL) 84,84,77
348    83    IND=0
349          I2MC=I2MCS
350          IF (DP.LT.DPMX) GO TO 84
351          DPMX=DP
352          XDMX=X
353    84    IPOP1=IPO+1
354          GO TO (92,85,87,88,92), IPOP1
355    85    IF (RF.EQ.1..OR.MXLF.EQ.1) GO TO 86
356          WRITE(*,98) X,DP,RF
357          GO TO 92
358    86    WRITE(*,98) X,DP
359          GO TO 92
360    87    IF (IDEP.EQ.0) WRITE(*,98) X,DP,RF,DLDG
361          IF (IDEP.GE.1) WRITE(*,98) X,DP,RF,DLDG,DOSI,DOSIS
362          GO TO 92
363    88    IF (DP.LT.D(1)) GO TO 92
364          DO 89 IY=1,ND
365          ARG=DPL-DL(IY)
366          IF (ARG.LT.0.) GO TO 90
367          Y(IY)=1.41421*SY*SQRT(ARG)
368          IF (X.NE.XCH) AR(IY)=AR(IY)+Y(IY)*DXA
369          IF (X.EQ.XCH) AR(IY)=AR(IY)-Y(IY)*(XS+DX-XCH)
370    89    CONTINUE
371          IY=ND+1
372    90    IY=IY-1
373          WRITE(*,91) X,DP,(Y(I),I=1,IY)
374    91    FORMAT (1X,F10.0,1PE10.3,0P10F5.0)
375    92    XS=X
376          DPLS=DPL
377          DLDGS=DLDG
378          IF (X.NE.XCH) GO TO 93
379          IMTCH=1
380          SXS=SX
```

```
381        SYS=SY
382        SZS=SZ
383        RETURN
384   93   IF (X.EQ.1..AND.DX.GT.1.) X=0.
385        X=X+DX
386        K=K+1
387        IF (X.GT.9.E6) RETURN
388        IF (IND.EQ.0.OR.DP.GT.D(MRL+1) OR.IRTP.LT.1) GO TO 25
389        IF (DPMX.LT.D(MRL+1)) WRITE(*,104) XDMX,DPMX
390   94   WRITE(*,*)
391        IF (IPO.EQ.3) WRITE(*,96)
392   96   FORMAT (4X,'DOSAGE',5X,'AREA')
393        IF (IPO.EQ.3) WRITE(*,99) (D(I),AR(I),I=ND,1,-1)
394        IF (IVD.EQ.1.AND.IPO.EQ.4) CALL VDPL(QTTL,SY,SZ,D(1),X,DX,DXA,XS,
395       1XCH,DP,DPA,SDEPL,4)
396        IF (K.GT.51) RETURN
397        DO 97 I=K,51
398   97   DS(I,1)=0.
399        RETURN
400   98   FORMAT (1X,F10.0,1P5E10.3)
401   99   FORMAT (1X,1P2E10.3)
402   100  FORMAT (15X,'SUM')
403   101  FORMAT (/1X,F10.0,' (M) IS DISTANCE TO ',E10.3,' (MG-MIN/M^3)')
404   102  FORMAT (/1X,F10.0,' (M) IS DISTANCE TO ',A12/)
405   103  FORMAT (/' W/2-MINUTE CORRECTION')
406   104  FORMAT (/' MINIMUM DOSAGE NOT ATTAINED',//4X,'XDMAX',9X,'DMAX',
407       $        /F10.0,6X,E10.3)
408   105  FORMAT (/' DOSAGE IS BEING SUMMED')
409        END
```

HD42.FOR

```
 1  C  FIT TO ORG 40 PAR FOR 4.2/ CGW
 2        SUBROUTINE HD42
 3        COMMON NQI,QT(6),TWL(6),D(10),DL(10)
 4        COMMON TIM,DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
 5       1BETA,SZ100,Z,RC,V,QS
 6        COMMON HDM(33),IPR(1),ND,IPO,I2MC,IMA,OPC,IMM,IDD,IHS,NOV,INP,MRL,
 7       1NMU,ID2,IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD
 8        DIMENSION FWT(10),FST(3),ALBT4(3),SZR4(3)
 9        DATA FWT/1.6,.89,.64,.52,.43,.37,.33,.3,.27,.25/
10        DATA FST/.7,1.,1.25/
11        DATA SYR4/6.82/
12        DATA ALBT4/3.33,1.4,1.02/
13        DATA SZR4/287.,12.84,6.97/
14        TF=1.8*TMP+32.
15        IF (TF.LT.50.) GO TO 4
16        IUT=UT+.5
17        IF (IUT.GT.10) IUT=10
18        IMT=(IM+1)/2
19        IF (TF.LE.80.) FT=EXP(3.6889-.046052*TF)
20        IF (TF.GT.80.) FT=EXP(3.4239-.042799*TF)
21  C     22. TIME AFTER FUNCTIONING
22  1     CALL READA (22,IRT,3,TIM)
23        IF (IRT.LT.0) GO TO 1
24        FEL=ALOG(FST(IMT)*FWT(IUT)*FT*120./TIM)
25        R=1.
26        IF (FEL.LT.-1.2) GO TO 3
27        R=EXP(.36464-.86189*FEL)
28        IF (FEL.GT..4) R=R-EXP(-.05129-1.6767*FEL)
29        IF (FEL.LE..4) R=R-EXP(-.24846-1.1373*FEL)
30  3     QT(1)=QS*R*NMU
31        SY100=SYR4
32        SZ100=SZR4(IMT)
33        ALFA=ALBT4(IMT)
34        BETA=ALBT4(IMT)
35        SYS=3.8
36        SZS=.2
37        SXS=SYS
38        RETURN
39  4     WRITE(*,5)
40  5     FORMAT(' TEMPERATURE FUNCTION NOT DEFINED BELOW 10 DEG C')
41        QT(1)=0.
42        RETURN
43        END
```

FTC3.FOR

```fortran
1   C  PEAK CONCENTRATION/ INS/ CON/ FUM/ SAO PER CGW-JHG
2          SUBROUTINE CDS
3          CHARACTER*1 IST
4          COMMON NQI,QT(6),TWL(6),CI(10),CL(10)
5          COMMON PR(1),DXT,H,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALF,SYR,BTA,
6         1SZR,Z,RC,V,QS,TEVP,SA,FL,FMW,CDM(8),FP,CDM1(8),Z0,CDM2(11)
7          COMMON IPR(1),ND,IPO,I2MC,IMA,IPC,IMM,IDD,
8         1IHR,NOV,INP,MRL,ID1,ID2,IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
9          DIMENSION ALFA(6),BETA(6),SY100(6,2),SZ100(6)
10         DIMENSION SY100C(2,3),SZ20C(2,3),BETAC(2,3)
11         DIMENSION IST(11),Y(10),AR(10)
12         DATA ALFA/1.0,1.0,1.0,.9,.8,.7/
13         DATA BETA/1.4,1.,.9,.85,.8,.75/
14         DATA SY100/9.,6.33,4.8,4.,3.,2.,27.,19.,12.5,8.,6.,4./
15         DATA SZ100/14.,11.,7.5,4.5,3.5,2.5/
16         DATA SY100C/41.19,31.18,66.56,30.98,26.17,29.33/
17         DATA SZ20C/3.,1.652,.797,1.934,.705,1.242/
18         DATA BETAC/1.344,.755,1.218,.949,1.182,1./
19         DATA IST/'A','B','C','D','E','F','N','I','U','S','W'/
20         DATA HK/0./
21         IF (IDEP.EQ.0) GO TO 42
22         WRITE(*,1)
23   1     FORMAT ('CONCENTRATION NOT DEFINED FOR INSTANTEOUS'
24        $' RELEASE OF VX OR HD')
25         RETURN
26   42    IF (IMTCH) 2,2,43
27   2     DO 3 I=1,ND
28         AR(I)=0.
29         CL(I)=LOG(CI(I))
30   3     CONTINUE
31         X=0.
32         DX=DXT
33         SDEPL=1.
34         Q=QT(1)
35         IS=1
36         IF (TWL(1).GT..083) IS=2
37   43    IMTCH=0
38         IF (IM.GT.8) GO TO 5
39         IF (IM.GT.6) GO TO 4
40         ALF=ALFA(IM)
41         SYR=SY100(IM,IS)
42         BTA=BETA(IM)
43         SZR=SZ100(IM)
44         GO TO 5
45   4     I=UT/2.235+1
46         IF (I.GT.3) I=3
47         MC=IM-6
48         BTA=BETAC(MC,I)
49         ALF=.5
50         SYR=SY100C(MC,I)
```

```
51        SZR=SZ20C(MC,I)*5**BTA
52   5    XC=1.E36
53        IF (TWL(1).EQ.1.E36) GO TO 6
54        Q=QT(1)/TWL(1)
55        XC=0.
56        IF (IS.EQ.1) GO TO 6
57        XC=EXP(ALOG(TWL(1)*UT*157.27)/.9294)
58   6    QOU=Q/UT
59        HKOU=HK/UT/60.
60        XCH=1.E36
61        IF (TIVCH.NE.1.E36) XCH=UT*TIVCH*60.+X
62        IF (IMTCH.EQ.1) GO TO 44
63        MXLF=0
64        TWHML=HML+HML
65        IC=ND
66        IND=0
67        IRTP=1
68        IF (IR.GT.4.AND.IR.LT.8) IRTP=0
69        CPMX=0.
70        CPLSAV=-87.5
71        XSAVE=0.
72   44   A=0.
73        B=0.
74        C=0.
75        IF (SXS.NE.0.) A=(SXS/.1522)**1.076-X
76        IF (SYS.NE.0.) B=100*(SYS/SYR)**(1./ALF)-X
77        IF (SZS.NE.0.) C=100.*(SZS/SZR)**(1./BTA)-X
78        WRITE(*,7)
79   7    FORMAT(/5X,'Q(MG)',4X,'TS(MIN)',3X,'HTS(M)',4X,'HML(M)',
80        +6X,'WND')
81        WRITE (*,8) QT(1),TWL(1),H,HML,UT,IST(IM)
82   8    FORMAT (3X,1PE9.3,4(1X,F9.3),4X,A2)
83        WRITE (*,9)
84   9    FORMAT(/4X,'ALF',2X,'SYR',4X,'BTA',3X,'SZR',8X,'SYS(M)',
85        +2X,'SZS(M)',2X,'XY(M)',3X,'XZ(M)',3X,'XC(M)')
86        WRITE (*,10) ALF,SYR,BTA,SZR,SYS,SZS,B,C,XC
87   10   FORMAT (1X,4F6.2,6X,1P5E8.1/)
88        IF (IVD.EQ.1) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,XCH,CP,CP,
89        1SDEPL,1)
90        IF (IMA.EQ.3) WRITE(*,11)
91   11   FORMAT (' FUMIGATION')
92        IF (IPO.NE.3) GO TO 13
93        WRITE(*,12) (CI(I),I=1,ND)
94   12   FORMAT('         CONCENTRATIONS',10F5.0)
95        WRITE(*,*)
96        WRITE(*,*) '        X        CP      CONTOUR HALF-WIDTHS'
97   13   IF (IPO.LT.3) WRITE(*,41)
98        IF (IMA.EQ.2) WRITE(*,*)'                    PPM'
99   14   IF (X.GT.XCH) X=XCH
100       DXA=DX
101       IF (X.GE.(DX*10.)) DX=DX*10.
102       DXA=DXA+DX
103       IF (X.EQ.0) X=1
104       SY=SYR*((X+B)*.01)**ALF
105       SZ=SZR*((X+C)*.01)**BTA
```

```
106        IF (IVD.EQ.1.AND.X.EQ.1.) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,
107       1XCH,CP,CP.SDEPL,2)
108        IF (IRTP.GT.0) GO TO 15
109        CALL PLRS (UT,TMP,PMH,IL,IM,IR,X,H,HML,IPC,IRTP)
110   15   IF (IMA.NE.3) GO TO 16
111        SYF=SY+(H*.125)
112        CP=QOU/(150.39770*SYF*(H+SZ+SZ))
113        GO TO 24
114   16   IF (MXLF) 18,18,17
115   17   CP=QOU/(150.39770*SY*HML)
116        GO TO 22
117   18   CP=QOU/(188.49556*SZ*SY)
118        TSZSQ=SZ*SZ*2.
119        HPZ=H+Z
120        HMZ=H-Z
121        VT=V*X/UT
122        FAC=0.
123        HML2=1.E36
124        ARG=(HMZ-VT)**2/TSZSQ
125        IF (ARG.LT.87.) FAC=FAC+EXP(-ARG)
126        ARG=(HPZ-VT)**2/TSZSQ
127        IF (ARG.LT.87.) FAC=FAC+RC/EXP(ARG)
128        ZFAC=0.
129        IF (HML.GT.1.E10.OR.MXLF.EQ.1) GO TO 21
130        DO 19 JJ=1,20
131        SMHML=TWHML*JJ
132        ARG=(SMHML-HPZ+VT)**2/TSZSQ
133        IF (ARG.GT.87.) GO TO 20
134        ZFAC=ZFAC+RC**(JJ-1)/EXP(ARG)
135        ARG=(SMHML-HMZ+VT)**2/TSZSQ
136        IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
137        ARG=(SMHML+HMZ-VT)**2/TSZSQ
:38        IF (ARG.LT.87.) ZFAC=ZFAC+RC**JJ/EXP(ARG)
139        ARG=(SMHML+HPZ-VT)**2/TSZSQ
140   19   IF (ARG.LT.87.) ZFAC=ZFAC+RC**(JJ+1)/EXP(ARG)
141   20   IF((FAC+ZFAC).NE.0.)HML2=(2.5066283*SZ)/(FAC+ZFAC)
142        IF (HML.GT.HML2.AND.(HML-HML2).LT.1) MXLF=1
143   21   RF=(FAC+ZFAC)/2.
144        CP=CP*RF
145   22   IF (X.LT.XC) GO TO 23
146        SX=.1522*((X+A)**.9294)
147        CF=CP*TWL(1)*UT*23.936537/SX
148   23   IF (HK.GT.0.) CP=CP/EXP(X*HKOU)
149   24   IF (CP.LT.1.E-35) GO TO 36
150        IF (IVD.EQ.1) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,
151       1XCH,CP,CP,SDEPL,3)
152        IF (IMA.EQ.2) CP=CP*24.45/FMW
153        CPL=LOG(CP)
154        IF (XSAVE.EQ.0..OR.CPL.GE.CPLSAV) GO TO 28
155        IND=1
156   25   IF (CPMX.LT.CI(IC)) GO TO 26
157        IF (CP.GT.CI(IC).OR.CPLSAV.LT.CL(IC)) GO TO 29
158        XLNA=ALOG(X)
159        XLNB=ALOG(XSAVE)
160        XLNC=XLNB+(XLNA-XLNB)*(CL(IC)-CPLSAV)/(CPL-CPLSAV)
```

```
161          XINT=EXP(XLNC)
162          IF (IVD.EQ.1) WRITE(*,'(F5.2)') SDEPL
163          WRITE (*,27) XINT,CI(IC)
164    26    IC=IC-1
165          IF (IC-MRL) 29,29,25
166    27    FORMAT (/1X,F10.0,'* ',1PE10.3)
167    28    IND=0
168          IC=ND
169          IF (CP.LT.CPMX) GO TO 29
170          CPMX=CP
171          XCMX=X
172    29    IF (IPO.NE.3) GO TO 32
173          SYRT2=1.41421*SY
174          Y(1)=0.
175          DO 30 IY=1,ND
176          ARG=CPL-CL(IY)
177          IF (ARG.LT.0.) GO TO 31
178          Y(IY)=SYRT2*SQRT(ARG)
179          IF (X.NE.XCH) AR(IY)=AR(IY)+Y(IY)*DXA
180          IF (X.EQ.XCH) AR(IY)=AR(IY)-Y(IY)*(XSAVE+DX-XCH)
181    30    CONTINUE
182          IY=ND+1
183    31    IY=IY-1
184          WRITE (*,39) X,CP,(Y(I),I=1,IY)
185          GO TO 35
186    32    IF (IPO.EQ.0.OR.IPO.EQ.4) GO TO 35
187          IF (RF.EQ.1.0.OR.MXLF.EQ.1) GO TO 34
188          WRITE (*,33) X,CP,RF
189    33    FORMAT (1X,F10.0,2X,1P2E10.3)
190          GO TO 35
191    34    WRITE (*,33) X,CP
192    35    IF (IND.EQ.1.AND.CPL.LT.CL(1+MRL).AND.IRTP.GT.0) GO TO 37
193          XSAVE=X
194          CPLSAV=CPL
195          IF (X.NE.XCH) GO TO 36
196          IMTCH=1
197          SXS=SX
198          SYS=SY
199          SZS=SZ
200          RETURN
201    36    IF (X.EQ.1..AND.DX.GT.1.) X=0.
202          X=X+DX
203          GO TO 14
204    37    IF (CPMX.LT.CI(1+MRL)) WRITE(*,39) XCMX,CPMX
205          IF (IPO.EQ.3) WRITE (*,40) (CI(I),AR(I),I=ND,1,-1)
206          IF (IVD.EQ.1.AND.IPO.EQ.4) CALL VDPL(Q,SY,SZ,CI(1),X,DX,DXA,XS,
207         1XCH,CP,CP,SDEPL,4)
208          RETURN
209    38    FORMAT (21X,10F5.0)
210    39    FORMAT (1X,F10.0,1PE10.3,0P10F5.0)
211    40    FORMAT (//5X,'C',8X,'AREA',/(1P2E10.3))
212    41    FORMAT (/9X,'X',8X,'CP',8X,'RF')
213          END
```

PLR3.FOR

```
 1  C  STACK PROGRAM/ PLUME RISE/ GROUND FIRE/ CGW
 2         SUBROUTINE PLRS (UR,TMP,PMM,IL,IM,IR,XI,HT,HML,IPC,IRTP)
 3         COMMON PDM(60),HS,DS,TSC,VS,RDE,P,HR,CR,PDZ(42)
 4         DIMENSION DELF(6),DTDZ(6),PT(6,3),ITT(12)
 5         DATA DXT /10./
 6         DATA G /9.8/
 7         DATA ZR /2./
 8         DATA CP /.24/
 9         DATA GI /.64/
10         DATA GC /.5/
11         DATA DELF/1.2,1.1,1.,1.,.9,.8/
12         DATA DTDZ/-.01,-.008,-.006,0.,.01,.037/
13         DATA PT/.05,.05,.1,.1,.15,.15,.05,.1,.15,.2,.25,.3,.1,.15,.2,.25,
14        1.3,.35/
15         DATA ITT/3,2,3,1,3,2,3,2,2,3,3,0/
16         IF (XI.EQ.0.) GO TO 30
17         IF (IPC.GT.1) GO TO 10
18         IRTP=1
19         RETURN
20     10  X=XI
21         IF (XI.LT.XMX) GO TO 20
22         X=XMX
23         IRTP=IRTP+1
24     20  IF (IR-6) 280,290,320
25     30  IRTP=-1
26         TA=TMP+273.
27         S=G*DTDZ(IM)/TA
28         IF (IL.NE.12) GO TO 60
29  C      16. ATMOSPHERIC PRESSURE
30     40  CALL READA (16,IRT,IA,PMM)
31         IF (IRT.LT.0) GO TO 40
32     60  PA=1013.*PMM/760.
33  C      23. OUTPUT CONTROL CODE
34     50  CALL DEF (23,IRT)
35         IF (IRT.EQ.0) READ(*,*,ERR=70) IPC
36         GO TO 80
37     70  CALL DEF (63,IRT)
38         GO TO 50
39     80  IF (IR.GT.6) GO TO 300
40  C      24. HEIGHT OF STACK
41     90  CALL READA (24,IRT,IA,HS)
42         IF (IRT.LT.0) GO TO 90
43  C      25. DIAMETER OF STACK
44    100  CALL READA (25,IRT,IA,DS)
45         IF (IRT.LT.0) GO TO 100
46  C      26. TEMPERATURE OF STACK
47    110  CALL READA (26,IRT,IA,TSC)
48         IF (IRT.LT.0) GO TO 110
49  C      27. VELOCITY OF EFFLUENT
50    120  CALL READA (27,IRT,IA,VS)
```

```fortran
 51         IF (IRT.LT.0) GO TO 120
 52  C      28. RELATIVE DENSITY OF EFFLUENT
 53  130    CALL DEF (28,IRT)
 54         IF (IRT.EQ.0) READ(*,*) RDE
 55  140    TS=TSC+273.
 56         F=0.
 57         IF (TS.LT.TA) WRITE(*,150)
 58  150    FORMAT(' DHH/DHB/DHBT NOTE: STK TMP LESS THAN AIR TMP')
 59         IF (TS.LT.TA) GO TO 160
 60         F=(TS-TA)/TS*G*VS*DS**2/4.
 61         IF (F.LE.55.) XA=14.*F**.625
 62         IF (F.GT.55.) XA=34.*F**.4
 63         XMX=3.5*XA
 64  160    IT=ITT(IL)
 65         IF (IT.NE.0) P=PT(IM,IT)
 66         IF (IT.NE.0) GO TO 170
 67  C      29. FROST PROFILE EXPONENT
 68         CALL DEF (29,IRT)
 69         IF (IRT.EQ.0) READ(*,*) P
 70  170    UZ=UR*(HS/ZR)**P
 71         IF (S.GT.0.) XMX=2.4*UZ/S**.5
 72         FM=RDE*VS*VS*DS*DS/4.
 73         IF (UZ.LT.1..AND.S.GE.0.) GO TO 200
 74         VR=VS/UZ
 75         IF (VR.LT.4) WRITE(*,180)
 76  180    FORMAT (' DHJ NOTE: VS/UZ LT 4')
 77         IF (S.LT.0.) WRITE(*,190)
 78  190    FORMAT (' DHJ NOTE: UNSTABLE MET CONDITIONS')
 79         DHJ=3.*VR*DS
 80         GO TO 210
 81  200    DHJ=4.*(FM/S)**.25
 82  210    IF (S.LE.0.) GO TO 220
 83         DHJB=1.5*(FM/UZ)**.333/S**.167
 84         IF (DHJB.LT.DHJ) DHJ=DHJB
 85  220    X=1.
 86         IF (IR.EQ.5.AND.IPC.EQ.0) X=XMX
 87         DELH=(VS*DS/UR)*(1.5+(2.68E-3*PA*((TS-TA)/TS)*DS))
 88         DHH=DELH*DELF(IM)
 89         WRITE(*,230)
 90  230    FORMAT (/8X,'X',8X,'DHH',7X,'DHB',6X,'DHBT',5X,'DHJ')
 91         DEL=1.6*(F**.333)/UZ
 92  240    IF (IR.EQ.5.AND.X.GT.XMX) X=XMX
 93         DHB=DEL*X**.667
 94         IF (S.LE.0.) GO TO 250
 95         DHB=2.5*(F/(UZ*S))**.333
 96         IF (UR.GE.1.) GO TO 250
 97         DHMTT=5.*(F**.25)/(S**.375)
 98         IF (DHMTT.LT.DHB) DHB=DHMTT
 99  250    DHJX=1.44*DS*(VS/UZ)**.667*(X/DS)**.333
100         IF (DHJX.GT.DHJ) DHJX=DHJ
101         DHBT=F**.333*X**.667/UZ*(1.065-6.25*DTDZ(IM))
102         IF (IPC.EQ.1.OR.IPC.EQ.3) WRITE(*,260) X,DHH,DHB,DHBT,DHJX
103         IF (IR.EQ.5.AND.X.GE.XMX) GO TO 270
104         IF (IR.EQ.6.AND.DHJX.GE.DHJ) GO TO 270
105  260    FORMAT (6F10.2)
```

```
106        IF (X.EQ.1.) X=0.
107        X=X+DXT
108        GO TO 240
109   270  WRITE(*,260) X,DHH,DHB,DHBT,DHJ,P
110        IF (IR.EQ.5) HT=HS+DHBT
111        IF (IR.EQ.6) XMX=X
112        IF (IR.EQ.6) HT=HS+DHJ
113        RETURN
114   280  DHBT=F**.333*X**.667/UZ*(1.065-6.25*DTDZ(IM))
115        HT=HS+DHBT
116        GO TO 360
117   290  DHJX=1.44*DS*(VS/UZ)**.667*(X/DS)**.333
118        IF (DHJX.GT.DHJ) DHJX=DHJ
119        HT=HS+DHJX
120        GO TO 360
121   C    30. HEAT RELEASED
122   300  CALL READA (30,IRT,IA,HR)
123        IF (IRT.LT.0) GO TO 300
124   C    31. CLOUD RADIUS
125   305  CALL READA (31,IRT,IA,CR)
126        IF (IRT.LT.0) GO TO 305
127        HT=0.
128        IF (IM.LT.4) GO TO 330
129        IF (IM.EQ.4) S=G*3.322E-4/TA
130        ROA=352320.*PMM/760./TA
131        RTS=S**.5
132        XMX=3.14159*UR/RTS
133        X=XMX
134        WRITE(*,310) XMX
135   310  FORMAT (' XMX=',F7.0)
136   320  FT=1.-COS(RTS*X/UR)
137        FB=G*HR/(3.14159*ROA*CP*TA)
138        IF (IR.EQ.8) GO TO 350
139        HT=(3.*FB*FT/(S*GI**3)+(CR/GI)**4)**.25-(CR/GI)
140        GO TO 360
141   330  WRITE(*,340)
142   340  FORMAT (' HEIGHT DEFINED FOR STABLE CONDITIONS ONLY')
143        RETURN
144   350  HT=(3.*FB*FT/(UR*GC*GC*S)+(CR/GC)**3)**.333-(CR/GC)
145   360  IF (HT.LT.HML) GO TO 370
146        HT=HML
147   370  WRITE(*,380) HT
148   380  FORMAT(' HTS=',F7.2)
149        RETURN
150        END
```

PSST3.FOR

```
 1 C  PASQUILL STABILITY CATEGORY SELECTOR/ TURNER/CGW
 2         SUBROUTINE STAB (U,IS,IL,IM,ID)
 3         COMMON SDM(68),SLA,SLO,CC,CH,AE,SD2(21),IHR,SD3(15)
 4         CHARACTER*1 ISTA,MTC
 5         CHARACTER*20 ADH
 6         CHARACTER*3 IMO,IMOT
 7         DIMENSION AC(4),IST(7,8),ISTA(6),IDC(12),SE(4)
 8         DIMENSION IMOT(12),SLAT(10),SLOT(10)
 9         DATA AC/15.,35.,60.,90./
10         DATA ISTA/'A','B','C','D','E','F'/
11         DATA IST/6,6,4,3,2,1,1,6,6,4,3,2,2,1,6,5,4,4,3,2,1,6,5,4,4,3,2,2,
12        15,4,4,4,3,3,2,5,4,4,4,4,3,3,4,4,4,4,4,3,3,4,4,4,4,4,4,3/
13         DATA IDC/0,0,3,3,4,4,5,5,5,6,6,7/
14         DATA IMOT /'JAN','FEB','MAR','APR','MAY','JUN','JUL','AUG',
15        8            'SEP','OCT','NOV','DEC'/
16         DATA VE,YRL /0.,0./
17         DATA SE /92.78,93.64,89.83,89./
18         DATA HY /182.62/
19         DATA PH /1.570796/
20         DATA PI /3.141593/
21         DATA P2 /6.283185/
22         DATA RD /57.2958/
23         DATA SLAT/33.7,40.,39.3,16.7,38.,40.,34.,38.,40.,46./
24         DATA SLOT/86.1,113.,76.,169.5,84.,87.5,92.,2*105.,120./
25         IF (VE.GT.0.) GO TO 1
26         WRITE(*,*) ' INPUT: YEAR(1986)'
27         READ (*,*) YR
28         DYO4=(YR-1976.)/4.
29         VE=79.4931+(DYO4*.9688)-AINT(DYO4)
30         IF ((DYO4-AINT(DYO4)).EQ.0.) YRL=1.
31  1      IF (IL.LT.11) GO TO 30
32 C        32. STATION LATITUDE AND LONGITUDE
33   10    CALL DEF(32,IRT)
34         IF (IRT.EQ.0) READ(*,*) SLA,SLO
35         GO TO 40
36   30    SLA=SLAT(IL)
37         SLO=SLOT(IL)
38   40    A=SLA/RD
39 C        33. MONTH,DAY,HOUR (JAN,01,1200)
40         CALL DEF(33,IRT)
41         IF (IRT.EQ.1) GO TO 80
42         READ(*,'(A3,1X,BN,A20)') IMO,ADH
43         READ(ADH,'(BN,I2,1X,I4)') ID,IHR
44   60    DO 70 IM=1,12
45         IF(IMO.EQ.IMOT(IM)) GO TO 80
46   70    CONTINUE
47         GO TO 40
48 C        34. CLOUD COVER (1/10),CLOUD HEIGHT (FT)
49   80    CALL DEF (34,IRT)
50         IF (IRT.EQ.0) READ(*,*) CC,CH
```

```
51         HRC=IHR/100.
52         HRS=(HRC-INT(HRC))/0.6+INT(HRC)
53         IF (IM.NE.0) GO TO 100
54  C      35. SUN ELEVATION ANGLE
55         CALL DEF(35,RT)
56         IF (IRT.EQ.0) READ(*,*) AE
57         GO TO 130
58    100  DJ=(IM-1)*31-IDC(IM)+ID
59         IF (IM.GT.2) DJ=DJ+YRL
60         DV=DJ-VE
61         IF (DV.LT.0.) DV=DV+365.
62         DT=DV
63         DO 110 I=1,4
64         IF (DT.LT.SE(I)) GO TO 120
65         DT=DT-SE(I)
66    110  CONTINUE
67    120  DL=SIN(PH*((I-1)+DT/SE(I)))*.4091
68         EQ=(10.*SIN((DV+89.)/HY*P2)+7.75*SIN((DV+78)/HY*PI))/60.
69         HDL=ACOS(-.014538/COS(A)/COS(DL)-(TAN(A)*TAN(DL)))/.2618
70         TC=12.+EQ+(SLO/15.-AINT(SLO/15.))
71         ISR=(((TC-HDL)-AINT(TC-HDL))*.6+AINT(TC-HDL))*100.
72         ISS=(((TC+HDL)-AINT(TC+HDL))*.6+AINT(TC+HDL))*100.
73         AE=ASIN(SIN(A)*SIN(DL)+COS(A)*COS(DL)*COS((HRS-TC)*.2618))*RD
74    130  I=0
75         IF (CC.EQ.10.AND.CH.LT.7000.) GO TO 190
76         IF (HRS.GT.(13.-HDL).AND.HRS.LT.(11.+HDL)) GO TO 140
77         I=-2
78         IF (CC.GT.4.) I=-1
79         GO TO 190
80    140  DO 150 I=1,4
81         IF (AE.LT.AC(I)) GO TO 160
82    150  CONTINUE
83         I=4
84    160  IF (CC.LT.6.OR.CH.GT.16000.) GO TO 190
85         IF (CC.GT.9.OR.CH.GE.7000.) GO TO 170
86         I=I-2
87         GO TO 180
88    170  I=I-1
89    180  IF (I.LT.1) I=1
90    190  I=I+3
91         J=U+1.
92         IF (U.GT.6.) J=8
93         IS=IST(I,J)
94         MTC=ISTA(IS)
95         WRITE(*,200) ISR,ISS,AE,MTC
96    200  FORMAT(' SR',I4,3X,' SS',I5,3X,' AE',F6.2,3X,' STAB ',A1)
97         RETURN
98         END
```

WOODS.FOR

```fortran
1          SUBROUTINE WOODS(U,ALFA,SY100,BETA,SZ100,WT)
2          DIMENSION UT(4),W(4,5),ALW(4,5),SYW(4,5),BTW(5),SZW(4,5),WTT(5)
3          CHARACTER*2 WTT,WT
4          DATA UT/.45,2.2,5.4,8.9/
5          DATA W/.089,.45,1.1,1.8,.089,.36,.8,1.3,.089,.36,.8,1.3,
6         $ .045,.22,.54,.89,.045,.13,.27,.45/
7          DATA ALW/.8,1.,1.,1.1,.8,3*1.,.8,3*1.,.8,7*1./
8          DATA SYW/12.8,12.1,12.,12.,18.2,17.5,16.8,14.5,
9         $ 23.5,22.5,19.,14.,29.,26.5,22.5,16.5,53.,36.,26.,23./
10         DATA SZW/8.97,9.66,2*10.35,12.96,3*13.78,14.59,
11        $ 3*15.4,4*20.,4*34.5/
12         DATA BTW/1.2,1.3,1.3,1.4,1./
13         DATA WTT/'DW','MW','CF','MS','RF'/
14   C     36. WOODS TYPE
15      10 CALL DEF(36,IRT)
16         IF (IRT.EQ.0) READ(*,30) WT
17      30 FORMAT(A2)
18         DO 40 I=1,5
19         IF (WTT(I).EQ.WT) GO TO 60
20      40 CONTINUE
21         WRITE(*,50)
22      50 FORMAT(' WOODS CODE NOT DEFINED')
23         CALL DEF(76,IRT)
24         GO TO 10
25      60 IF (U.GT.0.) GO TO 90
26         U=ABS(U)
27         DO 70 J=1,4
28         IF (W(J,I) .GE. U) GO TO 130
29      70 CONTINUE
30      80 ALFA=ALW(4,I)
31         SY100=SYW(4,I)
32         SZ100=SZW(4,I)
33         GO TO 140
34      90 DO 100  J=1,4
35         IF (UT(J).GE.U) GO TO 110
36     100 CONTINUE
37         J=4
38     110 IF (J.NE.1) GO TO 120
39         U=W(J,I)
40         GO TO 130
41     120 S=ALOG(W(J,I)/W(J-1,I))/ALOG(UT(J)/UT(J-1))
42         U=W(J-1,I)*(U/UT(J-1))**S
43         IF (U.GT.W(4,I)) GO TO 80
44     130 DUW=(U-W(J-1,I))/(W(J,I)-W(J-1,I))
45         ALFA=ALW(J-1,I)+DUW*(ALW(J,I)-ALW(J-1,I))
46         SY100=SYW(J-1,I)+DUW*(SYW(J,I)-SYW(J-1,I))
47         SZ100=SZW(J-1,I)+DUW*(SZW(J,I)-SZW(J-1,I))
48     140 BETA=BTW(I)
49         RETURN
50         END
```

DEF.FOR

```
 1          SUBROUTINE DEF(IQ,IRT)
 2          COMMON DDM(95),NOV,DD1(7),IR,DD2(6)
 3          DIMENSION IQT(40),IQI(7)
 4          DATA IQI/2,3,5,6,8,9,10/
 5          IF (IQ) 10,20,50
 6       10 IQQ=(-IQ)
 7          IQT(IQQ)=0
 8          RETURN                          ●
 9       20 DO 40 I=1,40
10       30 IQT(I)=0
11       40 CONTINUE
12          RETURN
13       50 IF (IQ.EQ.80) GO TO 140
14          IF (IQ.GT.40) GO TO 110
15          IF (IQ.EQ.40) GO TO 120
16          IF (IQ.EQ.39) GO TO 130
17          IF (IQT(IQ).EQ.0) GO TO 60
18          IRT=1
19          CALL QLIST(IQ,IRT)
20          RETURN
21       60 IRT=0
22          IF(IQ.NE.12.AND.IR.NE.2) WRITE(*,*)
23          CALL QLIST(IQ,IRT)
24          IQT(IQ)=1
25          IF (NOV-1) 70,90,100
26       70 WRITE(*,80)
27       80 FORMAT('  INPUT:'\)
28          RETURN
29       90 IF (IQ.EQ.2) WRITE(*,1001)
30          IF (IQ.EQ.3) WRITE(*,1007)
31          IF (IQ.EQ.5) WRITE(*,1003)
32          IF (IQ.EQ.6) WRITE(*,1004)
33          IF (IQ.EQ.8) WRITE(*,1005)
34          IF (IQ.EQ.9) WRITE(*,1006)
35          IF (IQ.EQ.17) WRITE(*,1012)
36          IF (IQ.EQ.36) WRITE(*,1024)
37          GO TO 70
38      100 IF (IQ.EQ.1) WRITE(*,2000)
39          IF (IQ.EQ.2) WRITE(*,2005)
40          IF (IQ.EQ.3) WRITE(*,2010)
41          IF (IQ.EQ.5) WRITE(*,2020)
42          IF (IQ.EQ.6) WRITE(*,2030)
43          IF (IQ.EQ.8) WRITE(*,2040)
44          IF (IQ.EQ.9) WRITE(*,2050)
45          IF (IQ.EQ.13.AND.IR.NE.3) WRITE(*,2060)
46          IF (IQ.EQ.13) WRITE(*,2070)
47          IF (IQ.EQ.17) WRITE(*,2080)
48          IF (IQ.EQ.21) WRITE(*,2090)
49          IF (IQ.EQ.23) WRITE(*,2095)
50          IF (IQ.EQ.36) WRITE(*,2110)
```

```
51          GO TO 70
52      110 IQQ=IQ-40
53          IQT(IQQ)=0
54          IF (NOV.GT.1) RETURN
55      115 IF (IQQ.EQ.1) WRITE(*,2000)
56          IF (IQQ.EQ.2) WRITE(*,2005)
57          IF (IQQ.EQ.3) WRITE(*,2010)
58          IF (IQQ.EQ.5) WRITE(*,2020)
59          IF (IQQ.EQ.6) WRITE(*,2030)
60          IF (IQQ.EQ.8) WRITE(*,2040)
61          IF (IQQ.EQ.9) WRITE(*,2050)
62          IF (IQQ.EQ.17) WRITE(*,2080)
63          IF (IQQ.EQ.21) WRITE(*,2090)
64          IF (IQQ.EQ.23) WRITE(*,2095)
65          IF (IQQ.EQ.36) WRITE(*,2110)
66          RETURN
67      120 IQQ=IRT
68          IF (IQQ.GT.0) GO TO 115
69          IF (IRT.EQ.-1) WRITE(*,601)
70          IF (IRT.EQ.-2) WRITE(*,602)
71          IF (IRT.EQ.-3) WRITE(*,603)
72          IF (IRT.EQ.-4) THEN
73          WRITE(*,604)
74          PAUSE
75          WRITE(*,605)
76          PAUSE
77          WRITE(*,606)
78          PAUSE
79          WRITE(*,607)
80          PAUSE
81          ENDIF
82          WRITE(*,600)
83          RETURN
84      130 WRITE(*,500)
85          PAUSE
86          WRITE(*,501)
87          PAUSE
88          RETURN
89      140 WRITE(*,*) ' LOC,SEA,MUN,AGN,REL,STB,WND'
90          DO 145 I=1,7
91      145 IQT(IQI(I))=1
92          NOV=0
93          RETURN
94  C-----------------------------------------------------
95  C CONTROL OPTION AND QUESTION FORMAT STATEMENTS
96  C-----------------------------------------------------
97      600 FORMAT(//
98          +' TABLE DISPLAY CODES  1 CONTROL OPTIONS',5X,
99          +'2 ASSESSMENT OPTIONS'/,22X,'3 OUTPUT OPTIONS'
100         +,6X,'4 ALPHABETIC LISTING'/)
101     601 FORMAT(//
102         +14X,'CONTROL OPTIONS'//,6X,'RST  RESTART'/,6X,'RSN  RESCAN'/,
103         +6X,'ALL  EXECUTE'/,6X,'STP  STOP'//,6X,'GTO  GO TO '
104         +'QUESTION NO. (GTO 3)'/,6X,'IRT  RETURN TO QUESTION NO.'/,
105         +6X,'INP  INPUT QUESTION NO.'//,6X,'HLD  HOLD VARIABLE '
```

```
106        +'(HLD HML)'/,6X,'RLS  RELEASE VARIABLE'//,6X,'TAB  DISPLAY'
107        +' TABLE'/,6X,'DSP  DISPLAY QUESTION DEFINITION'/,6X,'??? '
108        +' LIST OF DISPLAY CODES'/)
109    602 FORMAT(///
110        +16X,'ASSESSMENT CONTROLS'//,5X,'IMA=0  DOSAGE (DEFAULT)'/,
111        +9X,'1  CONCENTRATION (MG/CU M)'/,9X,'2  CONCENTRATION (PPM)'
112        +/,9X,'3  FUMIGATION CONCENTRATION'//,5X,'2MC=0  DO NOT'
113        +'USE 2-MINUTE CORRECTION'/,12X,'WITH GB AND VX VAPOR'/,
114        +9X,'2  USE 2-MINUTE CORRECTION WITH'/,12X,'GB AND VX'
115        +' VAPOR (DEFAULT)'//,5X,'MNR=0  NO EFFECTS, NO DEATHS'
116        +', 1% LETHALITY'/,9X,'1  NO DEATHS, 1% LETHALITY'/,
117        +9X,'2  1% LETHALITY'//,5X,'VDP=0  W/O VAPOR DEPLETION '
118        +'(DEFAULT)'/,9X,'1  W/VAPOR DEPLETION'/)
119    603 FORMAT(//
120        +15X,'OUTPUT CONTROLS'//,5X,'NOV=0  LIST QUESTIONS ONLY'/,9X,
121        +'1  LIST QUESTIONS AND OPTIONS'/,9X,'2  LIST OPTIONS WITH'
122        +' DEFINITIONS'//,5X,'OPO=0  OUTPUT SHORT HEADING (DEFAULT)'/,
123        +9X,'1  LIST DOSAGE AND DISTANCE'/,9X,'2  ABOVE PLUS COMPON'
124        +'ENTS OF D'/,9X,'3  CLOUD HALF-WIDTH WITH X'//,5X,
125        +'OPC=0  USE HT MAX FROM PLRS'/,9X,'1  LIST F(X), USE '
126        +'HT MAX'/,9X,'2  USE HT=F(X)'/,9X,'3  LIST AND USE F(X)'/)
127    604 FORMAT(//
128        +' CODE                        INPUT VARIABLE'/
129        +'  AGN    AGENT, SEE  DSP 6'/
130        +'  ALL    CONTROL WORD,EXECUTE PROGRAM'/
131        +'  ALF    SLOPE OF THE SIGMA-Y VERSUS X CURVE'/
132        +'  ARE    AREA OF PUDDLE                    (M^2)'/
133        +'  BPT    BOILING POINT                     (DEG K)'/
134        +'  BRT    BREATHING RATE                    (L/MIN)'/
135        +'  BTA    SLOPE OF THE SIGMA-Z VERSUS X CURVE'/
136        +'  CHT    CLOUD HEIGHT                      (FT)'/
137        +'  CRD    CLOUD RADIUS                      (M)'/
138        +'  DLX    CHANGE IN X (FIRST CYCLE)         (M)'/
139        +'  DST    DIAMETER OF STACK                 (M)'/
140        +'  FMV    MOLECULAR VOLUME              (CM^3 /GM MOLE)'/
141        +'  FMW    MOLECULAR WEIGHT'/
142        +'  FRO    SLOPE OF THE FROST WIND PROFILE'/
143        +'  GTO    CONTROL  GO TO SPECIFIED QUESTION'/
144        +'  HML    HEIGHT OF MIXING LAYER        (M)'/
145        +'  HLD    HOLD VALUE OF  SYMBOL'/
146        +'  HRL    HEAT RELEASED                     (CAL)')
147    605 FORMAT(//
148        +'  HRS    LOCAL STANDARD MILITARY TIME  (HRS)'/
149        +'  HST    HEIGHT OF STACK                   (M)'/
150        +'  HTS    HEIGHT OF SOURCE                  (M)'/
151        +'  ICC    CLOUD COVER                       (1/10)'/
152        +'  IDD    NUMBER OF THE DAY'/
153        +'  IMA    METHOD OF ASSESSMENT, SEE TAB 2'/
154        +'  IMM    NUMBER OF THE MONTH'/
155        +'  INP    CONTROL.  CLEAR INPUT BLOCK FOR QUESTION'/
156        +'  IRT    CONTROL.  RETURN TO SPECIFIED QUESTION'/
157        +'  LEN    DOWNWIND LENGTH OF PUDDLE         (M)'/
158        +'  LOC    LOCATION, SEE DSP 2'/
159        +'  MNR    MINIMUN RESPONSE LEVEL, SEE TAB 2'/
160        +'  MUN    MUNITION, SEE DSP 5'/
```

```
161        +'  NCI    NUMBER OF CONCENTRATIONS OF INTEREST'/
162        +'  NDI    NUMBER OF DOSAGES OF INTEREST'/
163        +'  NMU    NUMBER OF MUNITIONS'/
164        +'  NOV    NOVICE LEVEL'/
165        +'  NQI    NUMBER OF SOURCE INTERVALS')
166    606 FORMAT(//
167        +'  OPC    OUTPUT FOR STACK, SEE TAB 3'/
168        +'  OPO    OUTPUT CONTROL, SEE TAB 3'/
169        +'  PMM    ATMOSPHERIC PRESSURE                 (MM HG)'/
170        +'  QQQ    AIRBORNE SOURCE                      (MG)   '/
171        +'  RDE    RELATIVE DENSITY OF EFFLUENT'/
172        +'  REF    REFLECTION COEFFICIENT (DEFAULT=1)'/
173        +'  REL    METHOD OF RELEASE, SEE DSP 8'/
174        +'  RLS    RELEASE HOLD OF SYMBOL VALUE'/
175        +'  RSN    RESCAN FROM QUESTION 2'/
176        +'  RST    CONTROL.  RESTART'/
177        +'  SEA    SEASON, SEE DSP 3'/
178        +'  SKF    SKIN FACTOR FOR SUBJECT CLOTHING'/
179        +'  SLA    LATITUDE                             (DEG)'/
180        +'  SLO    LONGITUDE                            (DEG)'/
181        +'  SMH    SAMPLING HEIGHT                      (M)'/
182        +'  STB    STABILITY, SEE DSP 9'/
183        +'  SUN    SUN ELEVATION ANGLE                  (DEG)'/
184        +'  SUR    SURFACE TYPE, SEE DSP 13')
185    607 FORMAT(//
186        +'  SEV    SETTLING VELOCITY OF CLOUD CENTROID (DEFAULT=0) (M/SEC)'/
187        +'  SXS    SOURCE SIGMA -X                      (M)'/
188        +'  SYR    REFERENCE SIGMA -Y AT 100M           (M)'/
189        +'  SYS    SOURCE SIGMA -Y                      (M)'/
190        +'  SZR    REFERNCE SIGMA -Z AT 100M            (M)'/
191        +'  SZS    SOURCE SIGMA -Z                      (M)'/
192        +'  TEV    TIME OF EVAPORATION                  (MIN)'/
193        +'  TIM    TIME AFTER FUNCTIONING (INS,HD)      (MIN)'/
194        +'  TMC    TIME TO MET CHANGE                   (MIN)'/
195        +'  TMP    TEMPERATURE                          (DEG C)'/
196        +'  TST    TEMPERATURE OF STACK                 (DEG C)'/
197        +'  VAP    VAPOR PRESSURE                       (MM HG)'/
198        +'  CDP    VAPOR DEPLETION INDICATOR, SEE TAB 2'/
199        +'  VST    VELOCITY OF EFFLUENT FROM STACK      (M/SEC)'/
200        +'  WND    TRANSPORT WIND SPEED                 (M/SEC)'/
201        +'  WOO    WOODS TYPE, SEE DSP 36'/
202        +'  ZZO    ROUGHNESS LENGHT                     (CM)'/
203        +'  2MC    TWO MINUTE CONNECTIONS CONTROL, SEE TAB 2')
204    C-------------------------
205    C NOV=1 FORMAT STATEMENTS
206    C-------------------------
207   1001 FORMAT(8X,'AAD,DPG,EWA,JHI,LBG,NAP,PBA,PAD,RMA,UAD,EUR,NDF')
208   1007 FORMAT(8X,'WIN,SPR,SUM,FAL')
209   1003 FORMAT(8X,'105,155,8IN,500,750,M55,525,139,M23,4.2,NON')
210   1004 FORMAT(8X,'GA,GB,GD,GF,VX,BZ,HY,UD,HD,H1,H3,HT,LL,AC,CG,CK',
211        +              'DM,NA')
212   1005 FORMAT(8X,'INS,EVP,SEM,VAR,STK,STJ,FLS,FIR,IGL,EVS')
213   1006 FORMAT(8X,'A,B,C,D,E,F,U,S,W')
214   1012 FORMAT(8X,'GRA,NPR,NDF')
215   1024 FORMAT(8X,'DW,MW,CF,MS,RF')
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216  C-------------------------
217  C NOV-2 FORMAT STATEMENTS
218  C-------------------------
219  2000 FORMAT(8X,'O  SHORT LISTING FOR THE EXPERT'/,8X,'1  LISTS'
220       $' OPTIONS FOR MULTIPLE CHOISE QUESTIONS'/,8X,'2  DEFINES'
221       $' ALL OPTIONS FOR MULTIPLE CHOISE QUESTIONS'/,8X,'3  EXPL'
222       $'AINS PROGRAM INPUTS'/)
223  2005 FORMAT(8X,'AAD    ANNISTON ARMY DEPOT'/8X,
224       $'DPG    DUGWAY PROVING GROUND AND TOOELE ARMY DEPOT'/ 8X,
225       $'EWA    EDGEWOOD AREA,APG'/8X,'JHI    JOHNSTON ISLAND'/ 8X,
226       $'LBG    LEXINGTON-BLUE GRASS ARMY DEPOT'/ 8X,
227       $'NAP    NEWPORT AMMUNITION PLANT'/ 8X,'PBA    PINE BLUFF ARSENAL'
228       $/8X,'PAD    PUEBLO ARMY DEPOT'/ 8X,'RMA    ROCKY MOUNTAIN ARSENAL'
229       $/8X,'UAD    UMATILLA ARMY DEPOT'/8X,'EUR    USAEUR'/8X,
230       $'NDF    NOT DEFINED')
231  2010 FORMAT(8X,'WIN    WINTER'/8X,'SPR    SPRING'/8X,'SUM    SUMMER'/
232       $8X,'FAL    FALL')
233  2020 FORMAT(8X,'105    105-MM CARTRIDGE,M60,M360'/8X,
234       $'155    155-MM PROJECTILE,M110,M121A1'/8X,
235       $'8IN    8-INCH PROJECTILE,M126'/8X,'500    500-LB BOMB,MK94'/8X,
236       $'750    750-LB BOMB,MC-1'/8X,'M55    115-MM ROCKET,M55'/8X,
237       $'525    525-LB BOMB,MK116'/8X,'139    BOMBLET,M139'/8X,
238       $'M23    LAND MINE,M23'/8X,'4.2    4.2-INCH CARTRIDGE,M2A4'/8X,
239       $'NON    NONMUNITION')
240  2030 FORMAT (8X,'GA  TABUN',15X,'H1  HN-1,NITROGEN MUSTARD'/ 8X,'GB  SA
241       $RIN',15X,'H3  HN-3,NITROGEN MUSTARD'/ 8X,'GD  SOMAN',15X,'HT  60%
242       $HD & 40% T' /8X,'GF  EA 1212',13X,'LL  LEWISITE'/ 8X,'VX  EA 1701'
243       $,13X,'AC  HYDROGEN CYANIDE'/ 8X,'BZ  INCAP AGENT', 9X,'CG  PHOSGEN
244       $E'/ 8X,'HY  HYDRAZINE',11X,'CK  CYANOGEN CHLORIDE'/ 8X,'UD  UDMH',
245       $16X,'DM  ADAMSITE'/ 8X,'HD  DISTILLED MUSTARD', 3X,'NA  NOT AN AGE
246       $NT')
247  2040 FORMAT(8X,'INS    INSTANTANEOUS(EXPLOSIVE)'/8X,'EVP    EVAPORATION
248       $ FROM A PUDDLE FORMED BY A SPILL'/8X,'SEM    UNIFORM RELEASE FOR A
249       $FINITE TIME'/8X,'VAR    SOURCE DEFINED AS A NUMBER OF UNIFORM RELE
250       $ASES(MAX 6)'/8X,'STK    RELEASE OF HEATED EFFLUENT FROM STACK'/8X,
251       $'STJ    RELEASE FROM STACK WITH JET EFFECT'/8X,'FLS    FLASH FIRE
252       $FROM GROUND LEVEL'/8X,'FIR    FIRE BURNING FOR FINITE TIME'/8X,
253       $'IGL    M55 IGLOO FIRE'/8X,'EVS    EVAPORATION IN STILL AIR')
254  2050 FORMAT(8X,'A',5X,'VERY UNSTABLE'/ 8X,'B',5X,'UNSTABLE'/8X, 'C',5X,
255       $         'SLIGHTLY UNSTABLE'/,8X,'D',5X,'NEUTRAL'/,8X,'E',5X,
256       $         'SLIGHTLY STABLE'/,8X,'F',5X,'STABLE'/,8X,'U',5X,
257       $         'UNDEFINED'/,8X,'S',5X,'SELECT(PASQUILL)'/,8X,'W',5X,
258       $         'WOODS')
259  2060 FORMAT(8X,'NQI    NUMBER OF TIME INTERVALS')
260  2070 FORMAT(8X,'Q()    SOURCE FOR EACH INTERVAL'/,
261       $7X,'TQ()  CUMULATIVE TIME FROM BEGINNING OF FIRST')
262  2080 FORMAT(8X,'GRA    GRAVEL'/8X,'NPR    NONPOROUS(CONCRETE)'/8X,'NDF    NOT
263       $ DEFINED')
264  2090 FORMAT(8X,'FMW    MOLECULAR WEIGHT',/8X,'FMV    MOLECULAR'
265       $' VOLUME'/8X,'VAP    VAPOR PRESSURE (MM HG)'/8X,
266       $'BPT    BOILING POINT (DEG K)'/)
267  2095 FORMAT(8X,'O    USE HT MAX FROM PLRS'/,8X,'1    LIST F(X),'
268       $' USE HT MAX'/,8X,'2    USE HT=F(X)'/,8X,'3    LIST F(X),'
269       $' USE HT=F(X/)')
270  2100 FORMAT(8X,'GRA    GRAVEL, LOOSE EARTH'/8X,'NPR    NONPOROUS,
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271      $ CONCRETE, BLACKTOP'/8X,'NDF     NOT DEFINED'/' NOTE: THIS CODE
272      $ ONLY DETERMINES THE SIZE OF THE WETTED SURFACE')
273  2110 FORMAT(8X,'DW  DECIDUOUS, WINTER'/ 8X,'MW  MIXED, WINTER'/ 8X,
274      $'CF  CONIFEROUS FOREST'/ 8X,'MS  MIXED SUMMER'/ 8X,
275      $'RF  RAIN FOREST')
276   500 FORMAT(//
277      $'      THE OPERATOR MAY CONTROL THE LENGTH OF THE QUESTIONS BY'/
278      $' SPECIFYING THE NOVICE LEVEL. LEVEL 2 WILL DEFINE ALL OPTIONS,'/
279      $' LEVEL 1 WILL LIST THE OPTIONS AND LEVEL 0 WILL ONLY STATE THE'/
280      $' QUESTIONS. RESPONDING WITH QUESTION MARKS PROVIDES THE LEVEL'/
281      $' 2 LIST AND THE QUESTION IS REPEATED.'/
282      $'      THE SEQUENCE OF QUESTIONS IS DETERMINED BY THE ANSWERS'/
283      $' GIVEN.  UNITS ARE STATED FOR NUMERIC INPUTS. "FOREIGN" UNITS'/
284      $' MAY BE CONVERTED BY PRECEEDING THE NUMBER WITH THE CHARACTER  '/
285      $' CODE IDENTIFYING THE UNITS. TWO QUESTION MARKS WILL CAUSE THE '/
286      $' CODE LIST TO BE DISPLAYED.'/
287      $'      THE QUESTIONS TERMINATE WITH ALL OTHER INPUT.'/
288      $' HERE ONLY CONTROL OPTIONS OR DATA CHANGES MAY BE ENTERED.'/
289      $' AGAIN QUESTION MARKS WILL DISPLAY THE OPTIONS LIST. CONTROL '/
290      $' OPTIONS INCLUDE RESTART(RST), STOP(STP) AND GO TO(GTO) ANY'/
291      $' QUESTION NUMBER. THE CODE ALL WILL COMPLETE THIS INPUT AND'/
292      $' CAUSE THE DOWNWIND HAZARD TO BE COMPUTED.'/////)
293   501 FORMAT(/
294      $'      IF THE CHANGES MADE IN THE ALL QUESTIONS CAUSE THE'/
295      $' PROGRAM TO REACCESS ITS DATA BASE THE INPUT LOGIC IS RE-'/
296      $' SCANNED. THIS IS SHOWN BY A DISPLAY OF THE INPUT QUESTIONS,'/
297      $' BUT NO INPUT IS REQUIRED UNLESS NEW QUESTIONS ARE ASKED. THE'/
298      $' PROGRAM AGAIN STOPS AT THE ALL QUESTION, AND WILL PROCEED'/
299      $' WITH THE ANSWER ALL.'/'      WHEN THE DOWNWIND HAZARD ESTI-'/
300      $' MATE HAS BEEN MADE THE PROGRAM WILL TERMINATE AT THE ALL'/
301      $' QUESTION. THE OPERATOR MAY CHANGE INDIVIDUAL PARAMETER VALUES'/
302      $' [INCLUDING NOV] AND REPEAT THE RUN OR RESTART OR STOP.'/
303      $' A HOLD[HLD] MAY BE PLACED ON ANY VARIABLE IF YOU DO NOT WISH'/
304      $' ITS VALUE TO BE CHANGED BY RESCAN OF THE DATA BASE. INPUT HLD'/
305      $' AND THE VARIABLE CODE(EG. HLD HML). RLS WILL RELEASE THE HOLD.'/
306      $' FOR MORE INFORMATION SEE CHEMICAL SYSTEMS TECHNICAL REPORT'/
307      $' ARCSL-TR-82014.'///////)
308      END
```

UNT.FOR

```
1          SUBROUTINE UNT(UM,IA,PRT)
2          DIMENSION UMT(25),UC(25),DN25(18),MNE(34),IK(25)
3          CHARACTER*2 UM,UMT
4          CHARACTER*6 MNE
5          DATA UMT/'AT','BR','CM','DF','FT','SF','GM','HR','IN',
6        $ 'KT', 'LB','MT','PM','M3','MH','MB','OZ','SC','TM',
7        $ 'TN','GL', 'LT','ML','PT','QT'/
8          DATA UC/760.,750.,.01,1.,.3048,.0929,1000.,60.,.0254,
9        $ .5148, 4.53592E5,3.281,.01667,.001,.447,.75,28349.5,
10       $ .01667, 1.E9,9.0718E8,3.785E6,1.E6,1000.,4.732E5,
11       $ 9.464E5/
12         DATA DN25/1.0887,1.0083,1.268,.687,1.37,1.18,1.073,
13       $ 1.0222,1.12765,1.09,1.24,1.66,1.89,1.011,.7914,
14       $ .51,1.65,0./
15         DATA MNE/'   ATM','   BAR','    CM',' DEG F','    FT',
16       $ ' SQ FT','    GM','    HR','    IN','    KT','    LB'
17       $,'     M',' M/MIN','C M/MN',' MI/HR','    MB','    OZ'
18       $,'   SEC','TON(M)','   TON','   GAL','     L','    ML'
19       $,'    PT','    QT','MM HG','DEG C','SQ M','MG','MIN',
20       $'M/SEC','L/MIN','M', 'FT'/
21         DATA IK/26,26,33,27,33,28,29,30,33,31,29,34,31,32,31,
22       $ 26,29,30,7*29/
23    15 DO 1 IC=1,25
24         IF (UM.EQ.UMT(IC)) GO TO 2
25     1 CONTINUE
26         WRITE(*,6)
27     6 FORMAT (' UNIT CODES')
28         DO 9 I=1,5
29     9 WRITE(*,10) (MNE(II),UMT(II),II=I,25,5)
30    10 FORMAT (1X,5(A6,'=',A2,3X))
31         UM='ND'
32         RETURN
33     2 PRT=PRT*UC(IC)
34         IF (IC.EQ.4) PRT=(PRT-32)/1.8
35         IF (IC.LT.21) GO TO 8
36         IF (IA.LT.18) GO TO 3
37         WRITE(*,4)
38     4 FORMAT (' INPUT: AGENT DENSITY')
39         READ(*,*) DN25(18)
40     3 PRT=PRT*DN25(IA)
41     8 IO=IK(IC)
42         WRITE(*,7) MNE(IC),MNE(IO),PRT
43     7 FORMAT (1X,A6,' TO ',A5,E9.3)
44    14 RETURN
45         END
```

```
1          SUBROUTINE QLIST(IQ,IRT)
2          CHARACTER*1 MTC,AA1,AB1
3          CHARACTER*2 AGNT,AA2,WT
4          CHARACTER*3        MUNT,REL,LOCT,SEAT,SUR,SYM
5          CHARACTER*12 ADH
6          CHARACTER*30 QTAB
7          COMMON NQI,QT(6),TWL(6),D(10),DL(10)
8          COMMON PR(1),DXT,HT,HML,SXS,SYS,SZS,TIVCH,UT,BR,SF,TMP,ALFA,SY100,
9        +   BETA,SZ100,Z,RC,V,QS
10         COMMON TEVP,SA,FL,FMW,FMV,VP,BP
11         COMMON HS,DS,TSC,VS,RDE,FP,HR,CR
12         COMMON SLA,SLO,CC,CH,AE,PMM,Z0
13         COMMON LOCT(1),SEAT,MUNT,AGNT,AA1,REL,MTC,AA2,
14       $         SUR,WT,AB1,ADH,ADR,AD2
15         COMMON IPR(1),ND,IPO,I2MC,IMA,IPC,IMM,IDD,IHR,NOV,INP,MRL,NMU,ID2,
16       +   IDEP,IMTCH,IM,IR,IL,IRL,ISM,IVD,K33,K42
17         DIMENSION IQM(36),IQR(36),QTAB(37),SYM(37)
18         DATA IQR /63,43,44,4,45,46,0,47,48,9,13,12,0,24,0,41,49,21,
19       +          22,23,24,1,59,28,29,30,31,32,33,34,35,36,60,38,40,50/
20         DATA IQM / 10*1,4,9*1,4,10*1,2,3,2,1,1/
21         DATA QTAB/
22       $'YOUR NOVICE LEVEL: 3,2,1 OR 0 ','LOCATION                      ',
23       $'SEASON                        ','HEIGHT OF MIXING LAYER        ',
24       $'MUNITION TYPE                 ','AGENT TYPE                    ',
25       $'SPILL OR AIRBORNE SOURCE (MG) ','RELEASE TYPE                  ',
26       $'STABILITY TYPE                ','WINDSPEED (M/SEC)             ',
27       $'ALF, SYR(M), BTA, SZR(M)      ','TEMPERATURE (DEG C)           ',
28       $'Q()(MG), TQ()(MIN)            ','MOLECULAR WEIGHT              ',
29       $'ALL OTHER INPUT               ','ATMOSPHERIC PRESSURE (MM HG)  ',
30       $'SURFACE CODE                  ','TIME OF EVAPORATION (MIN)     ',
31       $'AREA OF WETTED SURFACE (SQ M) ','LENGTH OF SURFACE DOWNWIND (M)',
32       $'FMW,FMV,VAP(MM HG),BPT(DEG K) ','TIME AFTER FUNCTIONING (MIN)  ',
33       $'OUTPUT CONTROL CODE           ','HEIGHT OF STACK (M)           ',
34       $'DIAMETER OF STACK (M)         ','TEMPERATURE OF STACK (DEG C)  ',
35       $'VELOCITY OF EFFLUENT (M/SEC)  ','RELATIVE DENSITY OF EFFLUENT  ',
36       $'FROST PROFILE EXPONENT        ','HEAT RELEASED (CAL)           ',
37       $'CLOUD RADIUS (M)              ','STATION LATITUDE AND LONGITUDE',
38       $'MONTH,DAY,HOUR: (JAN,01,1200) ','CLOUD COVER(1/10),CLOUD HT(FT)',
39       $'SUN ELEVATION ANGLE (DEG)     ','WOODS TYPE                    ',
40       +'AND ROUGHNESS LENGTH (CM)     '/
41         DATA SYM/
42       $'NOV','LOC','SEA','HML','MUN','AGN','QQQ','REL','STB','WND',
43       $'   ','TMP','   ','FMW','   ','PMM','SUR','TEV','ARE','LEN',
44       $'   ','TIM','OPC','HST','DST','TST','VST','RDE','FRO','HRL',
45       $'CRD','   ','   ','   ','SUN','WOO','ZZO'/
46         1F (IQ.GT.36) RETURN
47         IF (IQ.EQ.17.OR.IQ.EQ.22.OR.IQ.EQ.16.OR.IQ.EQ.23.OR.
48       +IQ.EQ.29.OR.IQ.EQ.36) WRITE(*,*)
49         IF (IRT.EQ.1) GO TO 10
50         IF (IQ.EQ.13.AND.IR.NE.3) THEN
```

```
51          WRITE(*,104) IQ,QTAB(IQ),SYM(IQ)
52          RETURN
53          ENDIF
54          WRITE(*,100) IQ,QTAB(IQ),SYM(IQ)
55          IF (IQ.EQ.30.AND.IR.EQ.8) WRITE(*,107)
56          IF (IQ.EQ.29.AND.IVD.EQ.1) WRITE(*,106) QTAB(37),SYM(37)
57          RETURN
58       10 IF(IQ.EQ.13.OR.IQ.EQ.7) THEN
59          WRITE(*,105) IQ,QTAB(IQ),(QT(I),TWL(I),I=1,NQI)
60          RETURN
61          ENDIF
62          IC=IQR(IQ)
63          IN=IQM(IQ)
64          IF (IC.LT.43) WRITE(*,101) IQ,QTAB(IQ),SYM(IQ),
65         $(PR(IC+I-1),I=1,IN)
66          IF(IC.GT.42.AND.IC.LT.54) WRITE(*,102) IQ,QTAB(IQ),SYM(IQ),
67         $(LOCT(IC-42+I-1),I=1,IN)
68          IF (IC.GT.54) WRITE(*,103) IQ,QTAB(IQ),SYM(IQ),
69         $(IPR(IC-53+I-1),I=1,IN)
70          IF(IQ.EQ.29.AND.IVD.EQ.1)WRITE(*,106)QTAB(37),SYM(37),20
71          IF (IQ.EQ.30.AND.IR.EQ.8) WRITE(*,107)
72          RETURN
73      100 FORMAT(1X,I2,'.  ',A30,A3)
74      101 FORMAT(1X,I2,'.  ',A30,A3,4F10.2)
75      102 FORMAT(1X,I2,'.  ',A30,A3,2X,A3)
76      103 FORMAT(1X,I2,'.  ',A30,A3,3I7)
77      104 FORMAT(1X,I2,'. NQI,',A30,A3)
78      105 FORMAT(1X,I2,'.  ',A30,1P2E10.3,/(35X,2E10.3))
79      106 FORMAT(5X,A30,A3,F10.2)
80      107 FORMAT(17X,' FOR FIR (CAL/SEC)')
81          END
```

READA.FOR

```
1          SUBROUTINE READA(IQ,IRT,IA,PRT)
2          CHARACTER*80 CARD
3          CHARACTER*2 UM
4          CALL DEF(IQ,IRT)
5          IF(IRT.NE.0) RETURN
6          READ(*,'(BN,A80)') CARD
7          READ(CARD,10,ERR=12) PRT
8     10   FORMAT(BN,F12.0)
9          RETURN
10    12   READ(CARD,13,ERR=14) UM,PRT
11    13   FORMAT(BN,A2,F12.0)
12         CALL UNT(UM,IA,PRT)
13         IF (UM.NE.'ND') RETURN
14    14   CALL DEF(-IQ,IRT)
15         IRT=(-1)
16         RETURN
17         END
```

ERFF.FOR

```fortran
 1   C   ERROR FUNCTION (HASTINGS APPROXIMATION)
 2           FUNCTION ERFF (A)
 3           DATA A1/0.070523C78/,A2/0.042282u12/,A3/0.0092705272/
 4           DATA A4/0.0001520143/,A5/0.0002765672/,A6/.0000430638/
 5           DATA C/1./
 6           C=SIGN(C,A)
 7           Z=ABS(A)
 8           IF (Z.LT..000001) GO TO 1
 9           IF (Z.GT.4.) GO TO 2
10           ERR=((((((A6*Z+A5)*Z+A4)*Z+A3)*Z+A2)*Z+A1)*Z+1.)**16
11           ERR=ABS(1.-(1./ERR))
12           ERFF=ERR*C
13           RETURN
14   1       ERFF=0.
15           RETURN
16   2       ERFF=C
17           RETURN
18           END
```

IGLO.FOR

```
 1          SUBROUTINE IGLO(QTS,TWL,NQI,IMU,IA,IR)
 2          DIMENSION QTS(6),TWL(6),EFF(3),TWLT(3)
 3          DATA EFF/.022932,.001512,.000756/
 4          DATA TWLT/15.,20.,60./
 5          IF (IA.GT.2.OR.IMU.NE.6) GO TO 3
 6          IF (IA.EQ.2) GO TO 2
 7          DO 1 I=1,3
 8          QTS(I)=4.99E6*EFF(I)
 9        1 TWL(I)=TWLT(I)
10          NQI=3
11          IR=4
12          RETURN
13        2 QTS(1)=4.45E6*.00164
14          TWL(1)=5.
15          NQI=1
16          IR=3
17          RETURN
18        3 WRITE(*,*) ' IGL IS ONLY DEFINED FOR M55 WITH GB OR VX.'
19          RETURN
20          END
```

VDPL.FOR

```
 1          SUBROUTINE VDPL(QTTL,SY,SZ,D1,X,DX,DXA,XS,XCH,DP,DPA,SDEPL,INT)
 2          COMMON VDM(41),UT,VDM1(23),FP,VDM2(8),Z0,VDM3(13),
 3         +IPO,I2MC,IMA,VDM4(11),IM,IR,IL,VDM5(3),K33,K42
 4          DIMENSION FKMS(6),ZOT(12),DDD(10),DDL(10),DDBR(10),
 5         +ARD(10),PT(6,3),ITT(12),Y(10)
 6          DATA PT/.05,.05,.1,.1,.15,.15,.05,.1,.15,.2,.25,.3,.1,
 7         +.15,.2,.25,.3,.35/
 8          DATA ITT/3,2,3,1,3,2,3,2,2,3,3,0/
 9          DATA FKMS/.9,.8,.6,.4,.2,.05/
10          DATA ZOT/100.,.03,100.,.005,100.,10.,100.,100.,100.,
11         +100.,100.,100./
12          GOTO(101,102,103,104)INT
13     101  ITI=ITT(IL)
14          IF(K33.EQ.0.AND.IL.LT.12.AND.IM.LT.7) FP=PT(IM,ITI)
15          IF (K42.EQ.0.AND.IL.LT.12) Z0=ZOT(IL)
16          UZ=UT*.005**FP
17          USTR=FP*FKMS(IM)*UZ
18          DVF2=USTR/UZ
19          DVF1=DVF2*USTR
20          BINV=0.06*(19600.*USTR*Z0)**.45
21          DEPV=DVF1/(1.+DVF2*BINV)
22          WRITE(*,50)
23     50   FORMAT(/5X,'FP',7X,'FKMS',7X,'UT',7X,'USTR',
24         +6X,'BINV',6X,'DEPV',6X,'QTTL')
25          WRITE(*,60) FP,FKMS(IM),UT,USTR,BINV,DEPV,QTTL
26     60   FORMAT(1X,1P7E10.3)
27          DEPV60=DEPV*60.
28          RETURN
29   C      ENTRY VDPL1(SY,SZ,D1)
30     102  DO 10 I=1,10
31     10   ARD(I)=0.
32          DDMX=QTTL/(188.496*SY*SZ*UT)
33          DDD(1)=D1/10.
34          DDDL=(ALOG(DDMX)-ALOG(DDD(1)))/9.
35          DDL(1)=ALOG(DDD(1))
36          DO 20 I=2,10
37          DDL(I)=DDL(I-1)+DDDL
38          DDD(I)=EXP(DDL(I))
39     20   DDBR(I-1)=(DDD(I-1)+DDD(I))/2.
40          IF (IPO.NE.4) RETURN
41          IF (IMA.GT.0) GO TO 35
42          WRITE(*,30) (DDD(I),I=1,10)
43     30   FORMAT(/6X,'DOSAGE CONTOURS',10F5.0)
44          WRITE(*,31)
45     31   FORMAT(/7X,'X',7X,'DP',4X,'CONTOUR HALF-WIDTHS')
46          RETURN
47     35   WRITE(*,37) (DDD(I),I=1,10)
48     37   FORMAT(/7X,'CONC. CONTOURS',10F5.0)
49          WRITE(*,38)
50     38   FORMAT(/7X,'X',7X,'CP',4X,'CONTOUR HALF-WIDTHS')
```

```
51          RETURN
52  C       ENTRY VDPL2(X,DX,DXA,XS,XCH,DP,DPA,SDEPL)
53    103   DP=DP*SDEPL
54          DPA=DPA*SDEPL
55          IF (DPA.LE.0) RETURN
56          DPLA=ALOG(DPA)
57          DO 70 IY=1,10
58          ARG=DPLA-DDL(IY)
59          IF (ARG.LT.0.) GO TO 80
60          Y(IY)=1.41421*SY*SQRT(ARG)
61          IF (X.NE.XCH) ARD(IY)=ARD(IY)+Y(IY)*DXA
62          IF (X.EQ.XCH) ARD(IY)=ARD(IY)-Y(IY)*(XS+DX-XCH)
63    70    CONTINUE
64          IY=11
65    80    QD=0.
66          IF (IPO.GT.0) WRITE(*,'(F5.2)') SDEPL
67          IY=IY-1
68          DO 90 I=1,9
69    90    QD=QD+DDBR(I)*(ARD(I)-ARD(I+1))*DEPV60
70          SDEPL=(QTTL-QD)/QTTL
71          IF (SDEPL.LT.0.) SDEPL=1.E-20
72          IF (IPO.EQ.4) WRITE(*,100) X,DPA,(Y(I),I=1,IY)
73    100   FORMAT(1X,F10.0,1PE10.3,0P10F5.0)
74          RETURN
75  C       ENTRY VDPL3
76    104   WRITE(*,*) '    C OR D      AREA'
77          WRITE(*,'(1X,1P2E10.3)') (DDD(I),ARD(I),I=10,1,-1)
78          RETURN
79          END
```

```
 1          DATA HMLT/2*820.,710.,600.,420.,170.,2*1500.,1060.,620.,360.,
 2        1 170.,2*1670.,1080.,490.,440.,310.,2*1340.,945.,550.,360.,160.,
 3        2 2*540.,377.,215.,100.,50.,2*2310.,1277.,245.,150.,100.,
 4        3 2*3625.,1892.,200.,100.,80.,2*1470.,845.,220.,100.,80.,
 5        4 2*780.,750.,720.,530.,180.,2*1720.,1285.,850.,470.,140.,
 6        5 2*1970.,1245.,525.,360.,210.,2*1300.,925.,550.,400.,130.,
 7        6 4*2000.,1250.,500.,4*2000.,1250.,500.,4*2000.,1250.,500.,
 8        7 4*2000.,1250.,500.,2*740.,765.,790.,640.,430.,2*1500.,1215.,
 9        8 930.,560.,340.,2*1530.,1005.,480.,340.,250.,2*1230.,975.,720.,
10        9 470.,280.,2*430.,440.,450. 320.,130.,2*1170.,840.,510.,320.,120.,
11        $ 2*1440.,895.,350.,250.,140.,2*990.,715.,440.,260.,100.,
12        1 2*780.,705.,630.,520.,160.,2*1460.,1065.,670.,510.,160.,
13        2 2*1770.,1220.,670.,550.,220.,2*1270.,975.,680.,550.,140.,
14        3 2*1020.,550.,3*85.,2*2780.,1480.,3*185.,2*3290.,1785.,3*180.,
15        4 2*2010.,1050.,3*95.,2*1020.,550.,3*85.,2*2780.,1480.,3*185.,
16        5 2*3290.,1785.,3*180.,2*2010.,1050.,3*95.,2*370.,345.,320.,290.,
17        6 280.,2*1900.,1160.,420.,220.,200.,
18        7 2*2455.,1427.,400.,145.,130.,2*1145.,667.,190.,135.,115.,
19        8 2*700.,450.,200.,150.,100.,2*1200.,750.,300.,200.,150.,
20        9 2*1500.,1000.,500.,300.,200.,2*1000.,650.,300.,200.,150./
21         DATA QF/
22        $7.39E5,2.95E6,6.58E6,4.9E7,9.98E7,4.99E6,1.58E8,5.9E5,0.,0.,
23        $0.,2.72E6,6.58E6,0.,0.,4.54E6,0.,0.,5.22E6,0.,
24        $1.35E6,4.4E6,0.,0.,0.,0.,0.,0.,0.,2.72E6/
25         DATA SYSM/1.9,3.5,5.0,12.,17.,4.4,21.,1.7,0.,0./
26         DATA SZSM/.63,1.2,1.7,4.0,5.7,1.5,7.0,.6,0.,0./
27         DATA PMMT/747.,651.,760.,761.,737.,742.,755.,
28        $ 641.,628.,730.,752.,0./
29         DATA D1/.5,6.,10.,.4,2.5,4.3,2.,100.,150.,670.,810.,1180.,
30        $120.,320.,385.,1525.,1850.,1.E36,1.,12.,20.,.5,6.,10.,
31        $.5,6.,10.,2.,100.,150.,2.,100.,150.,1.,50.,75.,
32        $2.,100.,150.,1.E36,1.E36,1.E36,1.E36,1.E36,1.E36,
33        $1.E36,1.E36,31.,4.,2240.,1.E36/
34         DATA FMWT/140.1,267.4,159.1,27.02,98.92,61.48,162.18,182.18,
35        $ 180.2,170.08,204.54,189.4,207.35,32.05,60.1,337.4,277.57/
```

Blank

APPENDIX F

SAMPLE PROBLEMS

Blank

APPENDIX F

SAMPLE PROBLEMS

1.   GB EXAMPLE

Find the 'no deaths' distance resulting from the detonation of a GB-filled 8-inch projectile given the following conditions:

- Location: Pine Bluff Arsenal

- Date/Time: 29 July, 1200 local standard time

- Air temperature: 32 °C (90 °F)

- Wind speed: 3 m/sec

- Stability: B

2.   EXPLOSIVE M23 LAND MINE EXAMPLE

Determine the 1 percent lethality, no deaths, and distances for no effects from an explosive release of VX from an M23 land mine given the following conditions:

- Location: Umatilla Army Depot

- Date/Time: 15 January, 0800

- Temperature: 5 °C

- Wind speed: 4 m/sec

- Cloud cover: 10/10

- Cloud height: 3000 feet

3.   Pallet Example

Determine the 1 percent lethality distance after an explosion within a pallet of GB-filled M55 rockets given the following conditions:

- Location: Lexington-Blue Grass Army Depot

- Season: Summer

- Temperature: 25 °C

- Wind speed: 3 m/sec

- Stability: D

- Assume open terrain

- Assume a decontamination time of 1 hour for the evaporative source

- The surface type should be labeled "NDF", i.e., "not defined"

- The area of the liquid puddle formed is 549 m^2 and the downwind length is 9 m

- The evaporative source should be approximated as a normal volume with SXS = 0.83 m and SYS = 7.0 m

4. TON CONTAINER EXAMPLE

Determine the distances to the 1.0 and .01 parts per million (ppm) concentrations resulting from a spill of HD agent when both valves of a ton container are sheared given the following conditions:

Location: Edgewood Arsenal

Season: Summer

Temperature: 22 °C

Wind speed: 8 knots

Stability: E

Leak occurs outside on a gravel surface

Decontamination time: 20 minutes

Twenty percent of the agent fill escapes

5. IGLOO EXAMPLE

Determine the 1 percent lethality distance resulting from a fire in an igloo filled with 1800 M55 rockets containing agent GB given the following conditions:

- Location: Pine Bluff Arsenal

- Date/Time: 17 June, 1400 local standard time

- Air temperature: 80 °F

- Wind speed: 5 m/sec

- Clouds: 6/10 at 30,000 feet

o Run the model assuming

   (a) Wooded terrain (mixed summer forest)

   (b) Open terrain

Blank

INPUT:D2PC

| DOWNWIND HAZARD PROGRAM D2PC |

TYPE ? FOR DEFINITIONS

1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
INPUT:0

2. LOCATION   LOC
INPUT:PBA

3. SEASON   SEA
INPUT:SUM

5. MUNITION TYPE   MUN
INPUT:8IN

6. AGENT TYPE   AGN
INPUT:GB

8. RELEASE TYPE   REL
INPUT:INS

9. STABILITY TYPE   STB
INPUT:B

10. WINDSPEED (m/sec)   WND
 INPUT:3.
DI=   .5   6.0   10.0
12. TEMPERATURE (deg C)   TMP
 INPUT:32.
ALL OTHER INPUT
ALL

   1 MUN:8IN AGN:GB REL:INS WND= 3.0(M/S) TMP=32.0(C) PBA-SUM STB:B

  Q(MG)   TS(MIN)   HTS(M)   HML(M)   SXS(M)   SYS(M)   SZS(M)
4.937E+06 8.00E-02 .00E+00 1.77E+03 5.00E+00 5.00E+00 1.70E+00   B

W/2-MINUTE CORRECTION

     309. (M) IS DISTANCE TO 1% LETHALITY

     412. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

     1535. (M) IS DISTANCE TO NO EFFECTS

ALL OTHER INPUT
STP
Stop - Program terminated.

A>D2PC

```
                    | DOWNWIND HAZARD PROGRAM D2PC |
```

   TYPE ? FOR DEFINITIONS

1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
INPUT:0'

2. LOCATION   LOC
INPUT:UAD

3. SEASON   SEA
INPUT:WIN

5. MUNITION TYPE   MUN
INPUT:M23

6. AGENT TYPE   AGN
INPUT:VX

8. RELEASE TYPE   REL
INPUT:INS

9. STABILITY TYPE   STB
INPUT:S

10. WINDSPEED (m/sec)   WND
 INPUT:4.
 INPUT: YEAR(1986)
1986

33. MONTH,DAY,HOUR: (JAN,01,1200)
 INPUT:JAN,15,0800

34. CLOUD COVER(1/10),CLOUD HT(ft)
 INPUT:10,3000
SR 739   SS 1638   AE 2.22   STAB D
EDI= .44 1.76 4.00
ALL OTHER INPUT
ALL

  1 MUN:M23 AGN:VX REL:INS WND= 4.0(M/S) TMP= .0(C) UAD-WIN STB:S

   Q(MG)   TS(MIN) HTS(M)   HML(M)   SXS(M)   SYS(M)   SZS(M)
 5.220E+06 8.00E-02 .00E+00 3.20E+02 .00E+00 .00E+00 .00E+00 D

BRT= 25.   SKF=2.20E-02

W/2-MINUTE CORRECTION

     1116. (M) IS DISTANCE TO 1% LETHALITY

     1610. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

     2991. (M) IS DISTANCE TO NO EFFECTS

ALL OTHER INPUT
```

A>D2PC

```
                    | DOWNWIND HAZARD PROGRAM D2PC |

    TYPE ? FOR DEFINITIONS

1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
INPUT:0

2. LOCATION                        LOC
INPUT:LBG

3. SEASON                          SEA
INPUT:SUM

5. MUNITION TYPE                   MUN
INPUT:M55

6. AGENT TYPE                      AGN
INPUT:GB

8. RELEASE TYPE                    REL
INPUT:INS

9. STABILITY TYPE                  STB
INPUT:D

10. WINDSPEED (m/sec)              WND
 INPUT:3.
DI=     .5    6.0    10.0
12. TEMPERATURE (deg C)            TMP
 INPUT:25.
ALL OTHER INPUT
NMU 2
ALL
2. LOCATION                        LOC  LBG
3. SEASON                          SEA  SUM
5. MUNITION TYPE                   MUN  M55
6. AGENT TYPE                      AGN  GB
8. RELEASE TYPE                    REL  INS
9. STABILITY TYPE                  STB  D
10. WINDSPEED (m/sec)              WND      3.00
DI=     .5    6.0    10.0
12. TEMPERATURE (deg C)            TMP    25.00
ALL OTHER INPUT
NDI 1
INPUT: DI()S
0.1
ALL OTHER INPUT
ALL


   2 MUN:M55  AGN:GB  REL:INS  WND= 3.0(M/S)  TMP=25.0(C)  LBG-SUM STB:D

  Q(MG)   TS(MIN)  HTS(M)   HML(M)   SXS(M)   SYS(M)   SZS(M)
6.941E+06 8.00E-02  .00E+00 4.80E+02 4.40E+00 4.40E+00 1.50E+00   D

W/2-MINUTE CORRECTION

   11881. (M) IS DISTANCE TO   .100E+00 (MG-MIN/M^3)
```

```
ALL OTHER INPUT
SMD
ALL OTHER INPUT
NMU 13
REL EVP
ALL
  2. LOCATION                     LOC  LBG
  3. SEASON                       SEA  SUM
  5. MUNITION TYPE                MUN  M55
  6. AGENT TYPE                   AGN  GB
  8. RELEASE TYPE                 REL  EVP
  9. STABILITY TYPE               STB  D
 10. WINDSPEED (m/sec)            WND      3.00
DI=     .5      6.0    10.0
      SURFACE
 12. TEMPERATURE (deg C)          TMP     25.00

 17. SURFACE CODE                 SUR
 INPUT:NDF
 18. TIME OF EVAPORATION (min)    TEV
 INPUT:60.
 19. AREA OF WETTED SURFACE (sq m) ARE
 INPUT:549.
 20. LENGTH OF SURFACE DOWNWIND (m)LEN
 INPUT:9.
NDF  EVR=4.305E+03(mg/min-sq m)  AREA=5.490E+02(sq m)  VPR=2.856E+00
Q=6.487E+07(mg)  Q'=6.487E+07(mg)    TEV=2.745E+01(min)
ALL OTHER INPUT
SXS 0.83
SYS 7.
SMP
ALL


   13 MUN:M55  AGN:GB  REL:EVP  WND= 3.0(M/S)  TMP=25.0(C)  LBG-SUM STB:D

   Q(MG)   TS(MIN)  HTS(M)  HML(M)   SXS(M)   SYS(M)   SZS(M)
6.487E+07 2.74E+01  .00E+00 4.80E+02 8.30E-01 7.00E+00 1.00E-01  D

W/2-MINUTE CORRECTION

DOSAGE IS BEING SUMMED

     2260. (M) IS DISTANCE TO 1% LETHALITY


     3020. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

    16686. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STP
Stop - Program terminated.
```

```
                    TYPE ? FOR DEFINITIONS

          1. YOUR NOVICE LEVEL: 3,2,1 OR 0 NOV
          INPUT:0

          2. LOCATION                    LOC
          INPUT:EWA

          3. SEASON                      SEA
          INPUT:SUM

          5. MUNITION TYPE               MUN
          INPUT:NON

          6. AGENT TYPE                  AGN
          INPUT:HD

          8. RELEASE TYPE                REL
          INPUT:EVP
          9. STABILITY TYPE              STB
          INPUT:E
          10. WINDSPEED (m/sec)          WND
           INPUT:KT 8.
               KT TO M/SEC .412E+01
     DI=    2.0  100.0  150.0
           7. SPILL OR AIRBORNE SOURCE (mg) QQQ
           INPUT:1.64E8
               SURFACE
          12. TEMPERATURE (deg C)        TMP
           INPUT:22.

          17. SURFACE CODE               SUR
           INPUT:GRA
          18. TIME OF EVAPORATION (min)  TEV
           INPUT:20.
     GRA EVR=2.026E+02(mg/min-sq m)  AREA=2.509E+01(sq m)  VPR=8.197E-02
     Q=1.640E+08(mg)  Q'=1.017E+05(mg)   TEV=2.000E+01(min)
     ALL OTHER INPUT
     IMA 2
     DEFINE NCI
     NCI 2
     INPUT: CI()S
     .01,1.
     ALL OTHER INPUT
     ALL


      1 MUN:NON  AGN:HD  REL:EVP  WND= 4.1(M/S)  TMP=22.0(C)  EWA-SUM STB:E

        Q(MG)      TS(MIN)   HTS(M)    HML(M)      WND
       1.017E+05 2.000E+01  .000E+00 3.600E+02 4.118E+00      E

       ALF  SYR   BTA  SZR        SYS(M) SZS(M) XY(M)  XZ(M)  XC(M)
       .80  6.00  .80  3.50       1.7E+00 1.0E-01 2.0E+01 1.2E+00 2.7E+04


            X        CP        RF
                     PPM

          6.*  1.000E+00

        256.*  1.000E-02
     ALL OTHER INPUT
     STP
```

A>D2PC

| DOWNWIND HAZARD PROGRAM D2PC |

TYPE ? FOR DEFINITIONS

1. YOUR NOVICE LEVEL: 3,2,1 OR 0   NOV
INPUT:0

2. LOCATION   LOC
INPUT:PBA

3. SEASON   SEA
INPUT:SUM

5. MUNITION TYPE   MUN
INPUT:M55

6. AGENT TYPE   AGN
INPUT:GB

8. RELEASE TYPE   REL
INPUT:IGL

9. STABILITY TYPE   STB
INPUT:W

10. WINDSPEED (m/sec)   WND
 INPUT:5.

36. WOODS TYPE   WOO
 INPUT:MS
DI=   .5   6.0   10.0
ALL OTHER INPUT
NMU 1800
ALL
  2. LOCATION   LOC PBA
  3. SEASON   SEA SUM
  5. MUNITION TYPE   MUN M55
  6. AGENT TYPE   AGN GB
  8. RELEASE TYPE   REL IGL
  9. STABILITY.TYPE   STB W
 10. WINDSPEED (m/sec)   WND   5.0

36. WOODS TYPE   WOO MS
DI=   .5   6.0   10.0
ALL OTHER INPUT
ALL

```
1800 MUN:M55  AGN:GB  REL:IGL  WND= .5(M/S)  TMP= .0(C)  PBA-SUM STB:W

   Q(MG)    TS(MIN)   HTS(M)    HML(M)    SXS(M)    SYS(M)    SZS(M)
2.060E+08 1.50E+01  .00E+00 6.70E+02  .00E+00   .00E+00   .00E+00  MS
1.358E+07 2.00E+01
6.790E+06 6.00E+01

W/2-MINUTE CORRECTION

      1209. (M) IS DISTANCE TO 1% LETHALITY


      1795. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

      39065. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STB S
ALL
  2. LOCATION                    LOC  PBA
  3. SEASON                      SEA  SUM
  5. MUNITION TYPE               MUN  M55
  6. AGENT TYPE                  AGN  GB
  8. RELEASE TYPE                REL  IGL
  9. STABILITY TYPE              STB  S
 10. WINDSPEED (m/sec)           WND      5.0
  INPUT: YEAR(1986)
1986

33. MONTH,DAY,HOUR: (JAN,01,1200)
 INPUT:JUN,17,1400

34. CLOUD COVER(1/10),CLOUD HT(ft)
 INPUT:6,30000
SR 455    SS 1920     AE 63.40     STAB C
DI=      .5      6.0     10.0
ALL OTHER INPUT
ALL


1800 MUN:M55  AGN:GB  REL:IGL  WND= 5.0(M/S)  TMP= .0(C)  PBA-SUM STB:S

   Q(MG)    TS(MIN)   HTS(M)    HML(M)    SXS(M)    SYS(M)    SZS(M)
2.060E+08 1.50E+01  .00E+00 1.22E+03  .00E+00   .00E+00   .00E+00  C
1.358E+07 2.00E+01
6.790E+06 6.00E+01

W/2-MINUTE CORRECTION

      1450. (M) IS DISTANCE TO 1% LETHALITY


      1895. (M) IS DISTANCE TO NO DEATHS

W/O 2-MINUTE CORRECTION

      8962. (M) IS DISTANCE TO NO EFFECTS


ALL OTHER INPUT
STP
```